Asian Journal of Economic Modelling
ISSN(e): 2312-3656
ISSN(p): 2313-2884
DOI: 10.55493/5009.v10i3.4566
Vol. 10, No. 3, 160-177.

URL: www.aessweb.com

EXPORT DIVERSIFICATION IN ECONOMIC COMMUNITIES OF CENTRAL AFRICAN COUNTRIES: THE ROLE OF INFRASTRUCTURE

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Article History
Received: 21 February 2022
Revised: 1 July 2022
Accepted: 15 July 2022
Published: 5 August 2022

Keywords
Export diversification
Infrastructure
FMOLS
DOLS
ECCA.

JEL Classification :
F43; C22; E43.

ABSTRACT

Conscious of the low infrastructure development in Economic Community of Central African States (ECCAS), governments have invested important financial resources aimed at increasing the global stock of infrastructure, which indexes have raised from 11.13 in 2000 to 16.65 in 2018. In the same period, the average export concentration index slightly decreased from 4.92 in 2000 to 4.90 in 2014. Given the disproportionate improvement of infrastructure and export diversification, the study objective is to examine the effects of infrastructure on export diversification in ECCAS over the 2000–2016 period. Overall export diversification, and export diversification at extensive and intensive margins, are used as indicators. The fully modified ordinary least squares (FMOLS) and the dynamic ordinary least squares (DOLS) estimators are used for semi-parametric instrumental variable estimates that correct for serial correlation and endogeneity problems. The empirical results indicate that electricity and mobile phone infrastructure positively contribute to the overall and the export diversification along intensive margin, while transport infrastructure and internet negatively contribute to export diversification. The policy implications are that the stock of infrastructure should be increased quantitatively and qualitatively. The spatial distribution of infrastructure must depend on their capacity to produce a variety of tradable goods and services. The export diversification policies in ECCAS will prioritize infrastructure and the development of new export categories. Investment in infrastructure may be accompanied by trade and investment liberalization and by financial development.

Contribution/Originality: This is the first study that analyzes concomitantly the effects of transport, energy and information and communication technology (ICT) infrastructure on export diversification in ECCAS. Very few empirical research investigate export diversification determinants using the panel cointegration approach. Contrary to the majority of studies, we use the overall and the decomposed Theil export diversification indexes for intensive and extensive margins.

1. INTRODUCTION

By the end of the 1980s, under the economic crisis and the structural adjustment program, economic diversification in general and export diversification in particular have become one of the main challenges of ECCAS. The reliance on a limited number of goods that are subject to major price and volume fluctuations (agriculture, oil,

minerals, etc.) exposes ECCAS to different shocks, including a drop in its exports, a decline in terms of trade, and economic recession. To date, the issue of export diversification remains one of the main challenges in ECCAS, and policy makers are now conscious of the need for structural transformations to boost growth and trade and to limit their reliance on natural resources. ECCAS have faced several economic recessions because of the instability of prices of natural resources, which close to 60% of exports depend on. Agosin, Alvarez, and Bravo-Ortega (2012) strongly believe that export diversification can be a useful tool for poverty reduction and for ensuring socioeconomic stability. As mentioned by Collier (2014), international trade is highly dependent on infrastructure without which private initiatives are constrained by their inability to draw on essential contributions of transport, communications, energy, and water services. ECCAS' infrastructure deficiency is among major impediments to the expansion of exports. Conscious of this weakness, many ECCAS with the assistance of the international community[1] have invested in important financial resources aimed at increasing the quality and the stock of infrastructure. In fact, according to the Africa Infrastructure Development Index (AIDI) 2013 and 2016 reports, the global infrastructure development of ECCAS has risen from 11.13 in 2000 to 15.70 in 2010 and 16.65 in 2018. Concomitantly with the development of infrastructure in ECCAS, exports remain highly concentrated. The average export concentration index calculated from the IMF database decreased from 4.92 in 2000 to 4.85 in 2010 and rose to 4.90 in 2014. This relative stability prevents differences among ECCAS. In short, infrastructure improvement has not been compensated by a proportionate export diversification, and the disproportionate improvement of infrastructure and export diversification leads to the following questions: What are the effects of infrastructure on export diversification in ECCAS? What are the policy implications for export diversification?

There is a need to understand the driving role of infrastructure in export diversification in ECCAS before adjusting and/or setting export diversification policies. To the best of our knowledge, there are no empirical studies on export diversification specific to ECCAS regarding infrastructure.

The choice of ECCAS as field of study is justified by many reasons: First, the ECCAS' sub-regions are well endowed with natural resources, and the economies of a large majority of countries depend on agriculture and natural resource exploitation. Second, the ECCAS' exports are among the most concentrated in the world with an average export concentration index of 4.98. This concentration of exports means that ECCAS are still facing low integration into the world economy. Third, the ECCAS are most often affected by external shocks caused by drops in oil prices and other raw materials. The study contributes to the literature on exports diversification in three ways: First, to the best of our knowledge, the role of physical infrastructures, such as transport, energy and ICT, in the export diversification process is not well documented in Central Africa. Also, there is less empirical research on a comparative basis of the roles of transport infrastructure, electricity infrastructure and ICT infrastructure in fostering export diversification in the ECCAS' sub-regions. Second, this study contributes to the literature by implementing recently developed panel cointegration estimations. To the best of our knowledge, very few empirical researches has investigated export diversification determinants using the panel cointegration approach. Third, unlike the majority of studies that use overall export diversification, the present study makes use of the overall Theil and the decomposed Theil export concentration indexes, which enables us to observe determinants of diversification along the extensive and intensive margins. From this perspective, the focus on factors that affect diversification along the intensive margin is the novelty of this literature (Balavac, 2012).

Accordingly, the rest of this research is organized as follows: Section 2 presents the theoretical debate and empirical literature on the issue of liberalization in the relationship with export diversification; Section 3 explains the research methodology and estimation methods; Section 4 contains the empirical analyses and main findings; and Section 5 provides the concluding remarks and policy recommendations.

[1]The international community has invested these funds under the Infrastructure Consortium in Africa (ICA) and Partnership Infrastructure Program in Africa.

2. LITERATURE REVIEW

There are few empirical studies on the relationship between infrastructure and export diversification. Available research by Portugal-Perez and Wilson (2012) and Wessel (2019) reveals that lack of infrastructure increases the cost of production, reduces portability, and causes unnecessary delays in economic activities. Transport costs discourage export diversification (Parteka & Tamberi, 2011). The availability of good quality transport infrastructure reduces the distance and cost of accessing national and international markets (Matthee & Naudé, 2008). Because of the high cost of transport, landlocked countries face extra difficulties in diversifying their exports (Radelet & Sachs, 1998). Weak infrastructure is a major barrier to trade competitiveness and sustainable development in landlocked and small island countries (Mbekeani, 2007). The cost of international transport has a strong and significant negative effect on export diversification, especially in low-income countries, and arise from infrastructural inefficiency. Therefore, the low availability and the poor quality of infrastructure could be considered fixed production costs and a barrier for firms to operate in the international market (Do & Levchenko, 2009). As mentioned above, there is very limited empirical literature dealing with the direct effect of infrastructure on export diversification. Among them, Khan and Kumar (1997) demonstrated that growth in domestic investment has a positive and significant effect on export diversification. Parteka and Tamberi (2011) revealed that domestic investment plays an important role in enhancing both vertical and horizontal export diversification for East Asia. In ASEAN and SAARC[2]countries, Noureen and Mahmood (2016)found a positive effect of domestic investment in export diversification, whileBebczuk and Berrettoni (2006) found that domestic investment acts in favor of more export concentration, measured by the Herfindahl–Hirschman Index (HHI), and who argue that domestic firms focus more on taking advantage of specialization-based economies of scale rather than returns from export diversification. In the Middle East and North Africa over the period from 1984–2009,Alaya (2012)found that the accumulation of physical capital is among the factors that lead to more export diversification in the region. Osakwe, Santos-Paulino, and Dogan (2018)suggest that poor energy infrastructure negatively impacts industrialization and growth in Nigeria because it reduces the capacity utilization rates, makes domestic firms less competitive, and discourages banks and finance houses from lending to local manufacturing firms. The access to mobile phones contributes to overall export diversification and export diversification along the extensive margin (Giri, Quayyum, & Yin, 2019; Osakwe et al., 2018) but does not contributes to export diversification along the extensive margin (Giri et al., 2019). Better financial infrastructure helps to solve financial and liquidity barriers in the way of export diversification (Francois & Manchin, 2013; Rehman, Ding, Noman, & Khan, 2020).By the end of this empirical literature review, it can be observed that most empirical research focuses on export diversification but very few of them concomitantly analyze the effects of transport infrastructure, electricity infrastructure and ICT infrastructure on a comparative basis. The existing empirical literature focuses mainly on developing African and Latin American countries.

3. METHODOLOGY

3.1. Model Specification, Data Description, and Sources

3.1.1. Model Specification

The effect of infrastructure development on export diversification is estimated while controlling for the effects of other variables identified in the literature. Building on the empirical discussion, the following model (1) is specified to investigate the effect of infrastructure on export diversification.

[2] ASEAN and SAARC refer to the Association of Southeast Asian Nations and the South Asian Association for Regional Cooperation, respectively.

$$Theil_{it} = \beta_0 + \beta_1 Transp_{it} + \beta_2 Elect_{it} + \beta_3 Net_{it} + \beta_4 Tel_{it} + \beta_5 X_{it} + \theta_t + \lambda_i + \varepsilon_{it} \quad (1)$$

i = 1,…, n is any individual country involved in the sample, and t = 1,…, t is the time period.

The dependent variable ($Theil_{it}$) is Theil's indicator of export concentration for country *I* (exporting country) at time *t*. The higher the Theil index, the lower the export diversification. Theil's indicator of export concentration is a composite index, which can be decomposed into Theil's extensive margin (that measures the effect of the new export categories in a country's export mix) and Theil's intensive margin (that evaluates the equality of export values across export lines or the even distribution of export sales across the existing set of exported goods). The decomposition of the overall index of infrastructure development while accounting for the vector of control variables in Equation 1 gives Equations 2 and 3 to be estimated as follows:

$$Theilext_{it} = \beta_0 + \beta_1 Transp_{it} + \beta_2 Elect_{it} + \beta_3 Net_{it} + \beta_4 Tel_{it} + \beta_5 X_{it} + \theta_t + \lambda_i + \varepsilon_{it} \quad (2)$$

$$Theilint_{it} = \beta_0 + \beta_1 Transp_{it} + \beta_2 Elect_{it} + \beta_3 Net_{it} + \beta_4 Tel_{it} + \beta_5 X_{it} + \theta_t + \lambda_i + \varepsilon_{it} \quad (3)$$

Equation 2analyzes the effects of transport, electricity, internet and telephone infrastructures, and other control variables on export diversification at the extensive margin, while Equation 3analyzes the effects of transport, electricity, internet and telephone infrastructures, and other control variables on export diversification at the intensive margin.

In these equations, $Transp_{it}$ represents the transport composite index; $Elect_{it}$ is the installed electricity capacity in kwh per inhabitant; Tel_{it} is the percentage of mobile phone subscriptions in the population; and Net_{it} is the number of internet users per 100 inhabitants. X_{it}, is the vector of control variables identified in the literature by authors, such as Agosin et al. (2012);Giri et al. (2019);Mbekeani(2007);andParteka & Tamberi(2011), as determinants of export diversification. This vector is composed of $Rent_{it}$ that represents the natural resource rent, GDP_{it} is the per capita GDP, $Freetrade_{it}$ is the freedom to trade internationally, FDI_{it} is the net inflow of FDI in US dollars as a percentage of GDP, $Invest_{it}$ is investment freedom, $Findev_{it}$ is the financial development index, and β_i are the coefficients. Since a higher Theil index means a higher concentration of exports, we expect the coefficients of $Transp_{it}$, $Elect_{it}$, Net_{it}, Tel_{it}, GDP_{it}, $Freetrade_{it}$, FDI_{it}, $Findev_{it}$ and $Invest_{it}$ to have negative diversification effects on exports. θ_t, λ_i, and ε_{it} represent the time fixed effects, individual fixed effects, and the stochastic error term, respectively.

The introduction of any explanatory variable in the models is conditioned by the absence of multicollinearity. The variance inflation factor (VIF) procedure is used to test for the presence of multicollinearity among the explanatory variables in the models.

3.1.2. Data Description and Sources

The Theil and decomposed Theil export concentration indexes along extensive and intensive margins are the dependent variables of the different models. In estimating export concentration (diversification), the Herfindahl–Hirschman, Gini, and Theil indexes are the most widely used measures. The Theil export concentration indexes were chosen in this study to measure the extent to which a country's exports are diversified because it can be decomposed into the export concentration along intensive and extensive margins[3].

[3] For more detail, please refer to Cadot, Carrère, and Strauss-Kahn (2011).

The decomposition by Cadot et al. (2011)is used in this research, which focuses on the Theil and decomposed Theil diversification indexes into intensive and extensive margins. Regressions are run using intensive and extensive margins as dependent variables to shed light on the intensive margin of export growth that seems to be neglected in the empirical literature but enables a better understanding of the sources of diversification. Data were extracted from different sources, which are detailed in Appendix A1.

The study covers nine countries out of 11 from the ECCAS zone. These countries are Angola, Cameroon, Chad, the Central African Republic, the Republic of Congo, the Democratic Republic of the Congo (DRC), Gabon, Burundi and Rwanda. São Tomé and Principe and Equatorial Guinea are excluded from the study because of insufficient data. The choice of the ECCAS is justified by the fact that this sub-region is a combination of rich natural resource countries and non-rich natural resource countries. Countries in the region are among the most concentrated in the world and are mostly affected by external shocks caused by drops in oil prices and other raw materials.

3.2. Estimation Techniques

3.2.1. Tests for Univariate Integration and Multivariate Cointegration

To estimate the coefficients of Equations 1, 2 and 3, the first step is to examine the time series properties of all the variables in order to determine if their variances and covariances are finite, independent of time, or stationary. The principle of testing for cointegration is to verify whether two or more integrated variables move together over time in such a way that short-term disturbances will be corrected in the long-term. Pedroni (2004) proposed two cointegration tests: panel tests and group tests. The first group is "within dimension" and includes the panel-v, the panel rho(r), the panel nonparametric (Phillips–Perron or PP) and panel parametric (augmented Dickey–Fuller or ADF) statistics. The second group is based on the "between dimension" method (i.e., group mean panel cointegration statistics test) and includes three statistics (group rho-statistic, group PP-statistic, and group ADF-statistic). The seven Pedroni tests are based on the estimated residuals from the following long-run model:

$$Theil_{it} = \beta_o + \sum_{j=1}^{m} \beta_{ji} X_{jit} + \varepsilon_{it} \qquad (4)$$

Where i = 1 . . . N are countries in the panel and t = 1…. T refers to the time period. The parameter $\boldsymbol{\beta}_o$ allows for the possibility of country-specific fixed effects.

The panel cointegration test is derived from Kao (1999). This test can be performed from Equation 5 below:

$$\varepsilon_{it} = \rho \varepsilon_{it-1} + \omega_{it} \qquad (5)$$

In Equation 5, $\varepsilon_{i t-1}$is obtained from Equation 4. The null hypothesis is $H0$: $\rho = 1$ (no cointegration), while the alternative hypothesis is $H1$: $\rho<1$. Once the variables are found to be cointegrated, the next step is to estimate the long-run coefficients. Since the use of non-stationary variables in ordinary least squares (OLS) can lead to spurious regressions, we employ two different approaches, the *FMOLS and DOLS*.

3.2.2. Estimation of Long-Run Elasticities: FMOLS and DOLS

To establish the robustness of our results, we estimated the coefficients in Equations 1, 2 and 3byemploying several panel regression techniques, specifically fixed effects (FE) and random effects (RE), that enable us to detect the existence of individual specific effects that are not correlated with the independent variables. These analyses are completed by FMOLS and DOLS. FMOLS is a semi-parametric instrumental variable estimate that corrects for serial correlation and endogeneity problems. This method is designed to eliminate the asymptotic bias term of the ordinary least squares parameter. The FMOLS technique yields consistent parameters, even with a small sample size. The FMOLS method overcomes problems of endogeneity, serial correlation, omitted variable bias and measurement errors and allows for the heterogeneity of the long-run parameters (Bashier & Siam, 2014; Fereidouni, Al-Mulalia, & Mohammed, 2014). The FMOLS method also estimates a single cointegrating relationship, which is a

combination of I(0) and/or I(1) variables (Bashier & Siam, 2014). According to Phillips (1995), the technique is robust to stationary and non-stationary series. Also, it is argued that even when there is no cointegration relationship, the FMOLS method produces consistent and efficient estimates. To test the robustness of the analyses, we also estimate a regression coefficient using the DOLS approach developed byStock and Watson (1993). DOLS estimators are better than alternative estimators of long-run parameters, such as Johansen (1988) and Phillips and Hansen (1990). DOLS allows for variables of different integration orders and tackles any possible simultaneity bias within regressors and provides valid estimations, even in the presence of endogenous independent variables. DOLS also deals with simultaneity and small sample biases by including leads and lags (Kurozumi & Hayakawa, 2009). According to Masih and Masih (1996), the DOLS method is able to regress any I(1) variable on other I(1) or I(0) variable and on the lags and leads of the first differences of any I(1) variables.

4. RESULTS AND DISCUSSIONS

Our results and discussion are presented in three stages. In the first stage, we present descriptive statistics results; in the second stage, we present and discuss the results from econometric analyses; and in the third stage, we carry out the robustness check.

4.1. Descriptive Statistics

The results of the descriptive analyses in Table 1show that the exports are highly concentrated in ECCAS from 2000–2016. The overall export concentration index varies from a minimum value of 2.38 to a maximum value of 6.33, with an average of 4.98. There is a high difference between export concentration along intensive and extensive margins. Standard deviations are a bit higher for overall export concentration, export concentration along the extensive and intensive margins, transport, and freedom to trade internationally. The standard deviations of the remaining variables are higher, and it demonstrates higher differences among countries in the sample as far as the variables are concerned.

Table 1. Descriptive statistics results.

Variable	Average	Std. Dev.	N.	Min.	Max.
Theil	4.984	0.8182	150	2.38	6.33
Theilext	1.011	0.884	150	0.01	2.68
Theilint	3.975	1.127	150	2.27	5.98
Transp	4.195	3.7118	150	0.237	14.128
Elect	323.220	693.130	150	0.462	2626.185
Findev	0.0891	0.0305	150	0.024	0.158
Net	4.500	7.765	150	0.005	48.052
Rent	25.700	15.743	150	5.57	61.94
Freetrade	5.381	0.7827	150	3.135	7.190
Invest	39.60	14.266	150	10	70
GDP	2083.834	2811.462	150	218.283	20333.940
FDI	4.161	7.816	150	-6.054	64.38
Tel	32.841	37.413	150	0.032	171.375

As expected, in Table 2, overall export concentration (Theil) and transport infrastructure, electricity infrastructure, freedom to trade internationally and investment freedom are negatively and significantly related, meaning that any increase in the value of these variables results in export diversification. However, Theil's overall export concentration index is positively associated with natural resource rent, GDP, FDI, financial development, internet use and mobile phone use, meaning that an increase in one of these variables results in overall export concentration. Again, as expected, export concentration along the extensive margin (Theilext) and transport infrastructure, electricity infrastructure, freedom to trade internationally and financial development are negatively related. This means that any increase in the value of these variables results in export diversification along the extensive margin.

Table 2. Correlation analysis.

Variable	Theil	Theilext	Theilint	Transp	Elect	Rent	Freetrade	Invest	GDP	FDI	Findev	Net	Tel
Theil	1												
Theilext		1											
Theilint			1										
Transp	-0.374***	-0.042	-0.242***	1									
Elect	-0.241***	-0.210***	-0.011	-0.245***	1								
Rent	0.567***	0.064	0.360***	-0.307***	0.030	1							
Freetrade	-0.067	-0.307***	0.193***	0.165**	-0.080	-0.018	1						
Invest	-0.185***	0.123	-0.228***	0.061	-0.500***	-0.422***	0.180	1					
GDP	0.415***	0.432***	-0.040	-0.118*	-0.235***	0.345***	0.173**	0.133	1				
FDI	0.115	0.104*	0.001	-0.221***	0.001	0.096	0.009	0.028	0.034	1			
Findev	0.201***	-0.128*	0.251**	0.105*	-0.446***	-0.036	0.245***	0.349***	0.307***	-0.166**	1		
Net	0.065	0.125*	-0.050	-0.016	-0.133**	-0.032	0.077	0.250***	0.518***	0.022	0.346***	1	
Tel	0.024	0.098	-0.058	-0.142**	0.157**	0.105*	0.163**	0.103*	0.541***	0.000	0.271***	0.797***	1

Note:***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.

However, the export concentration along the extensive margin is positively associated with the natural resource rent, investment freedom, GDP, FDI, internet use and mobile phone use, meaning that an increase in one of these variables results in export concentration along the extensive margin.

The export concentration along the intensive margin (Theilint) and transport infrastructure, electricity infrastructure, investment freedom, GDP, internet use and mobile phone use are negatively related, meaning that an increase in the value of any of these variables results in export diversification along the intensive margin. However, export concentration along the intensive margin is positively associated with natural resource rent, freedom to trade internationally, FDI and financial development, meaning that an increase in one of these variables results in export concentration along the intensive margin.

However, it remains important to carry out econometric analyses to investigate the relationship between the infrastructures and export diversification in the ECCAS.

4.2. Econometric Analyses

Before we validate and comment on our econometric analyses, we first present the results of the preliminary analyses. The results from the Im and Pesaran panel unit root tests in Table 3 indicate that the null hypothesis of a unit root cannot be rejected for the variables' export concentration along the extensive margin and FDI at level, but all the other variables are trend stationary at level.

Table 3. Im and Pesaran panel unit root test results.

Variables	Level		First difference		Decision
	Statistic	Prob.	Statistic	Prob.	
Theil	4.609	1.000	-1.676	0.047**	I(1)
Theilint	1.560	0.941	-2.268	0.011*	I(1)
Theilext	-0.239	0.405	-3.828	0.000***	I(0)
Elect	-2.430	0.008***	-	-	I(1)
Transp	-2.737	0.003***	-	-	I(1)
Rent	0.356	0.639	-6.707	0 .000***	I(1)
FDI	1.488	0.931	-5.207	0.000***	I(0)
Freetrade	0.031	0.513	-14.451	0.000***	I(0)
Invest	8.134	1.000	-6.620	0 .000***	I(1)
GDP	0.967	0.833	-2.425	0.008***	I(1)
Findev	4.609	1.000	-1.676	0.047**	I(1)
Net	1.560	0.941	-2.268	0.0117*	I(1)
Tel	-0.239	0.405	-3.828	0.000***	I(1)

Note:***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.

Table 4 reports the within and between dimension results of the Pedroni panel cointegration tests. The results of the heterogeneous panel tests (Pedroni,2004) indicate that the null hypothesis of no cointegration can be rejected at the 1%level of significance except for the panel rho-statistic and the group rho-statistic. Therefore, there is a long-term relationship between variables of the model. The Kao (1999) cointegration test confirms the existence of a cointegration relationship between the variables of the different models.

The results from the correlation analyses in Table 2 show no evidence of collinearity. These conclusions are supported by the VIF test in Table 5, which show the absence of collinearity among the explanatory variables. In fact, the tolerance is high, meaning that just 10.5% to 77% of the variance is common to all four independent variables.

Table 4. Pedroni and Kao cointegration tests.

Pedroni Cointegration Test								
Alternative hypothesis: common AR coefficients (within-dimension)								
Statistic	Model (Theil, Theil extensive and Theil intensive as dependent variables							
	Theil		**Theil extensive**		**Theil intensive**		**Concent.**	
	Value	**Prob.**	**Value**	**Prob.**	**Value**	**Prob.**	**Value**	**Prob.**
Panel v-Statistic	0.587	0.278	1.926	0.028**	-0.780	0.783	0.124	0.450
Panel rho-Statistic	1.346	0.911	-0.094	0.422	0.929	0.833	-0.311	0.377
Panel PP-Statistic	-4.795	0.000***	-6.280	0.000***	-5.668	0.000***	-16.453	0.000***
Panel ADF-Statistic	-4.734	0.000***	-5.701	0.000***	-4.646	0.000***	-11.372	0.000***
Alternative hypothesis: individual AR coefficients (between-dimension)								
Statistic	Model (Theil. Theil extensive and Theil intensive as dependent variables							
	Theil		Theil extensive		Theil intensive		Concent.	
	Value	Prob.	Value	Prob.	Value	Prob.	Value	Prob.
Group rho-statistic	2.956	0.998	1.659	0.960	2.317	0.989	1.497	0.933
Group PP-statistic	-12.244	0.000	-6.369	0.00***	-5.747	0.000***	-14.811	0.000***
Group ADF-statistic	-6.681	0.000	-5.310	0.000***	-3.776	0.010***	-9.018	0.000***

Kao Cointegration Test			
Dependent Variable	**Values of:**	**t-Statistic**	**Prob.**
Theil	ADF	-1.749	0.040**
	Residual variance	0.101	
	Heteroskedasticity and autocorrelation-consistent variance	0.057	
Theilext	ADF	-2.486	0.006***
	Residual variance	0.072	
	Heteroskedasticity and autocorrelation-consistent variance	0.052	
Theilint	ADF	-2.366	0.009***
	Residual variance	0.101	
	Heteroskedasticity and autocorrelation-consistent variance	0.072	
Concent.	ADF	1.759	0.039**
	Residual variance	0.002	
	Heteroskedasticity and autocorrelation-consistent variance	0.001	

Notes: The test statistics are asymptotically distributed as standard normal. An automatic lag length was selected according to the Schwarz Information Criterion (SIC). *** and ** indicate significance at the1% and 5% levels, respectively.

Table 5. Collinearity analysis (VIF test results).

Theil		**Transp**	**Elect**	**Rent**	**Freetrade**	**Invest**	**GDP**	**FDI**	**Findev**	**Net**	**Tel**
Collinearity statistics	Tolerance	0.722	0.405	0.535	0.837	0.481	0.503	0.895	0.626	0.271	0.229
	VIF	1.385	2.472	1.870	1.195	2.078	1.988	1.117	1.597	3.687	4.364

With regard to the FE and RE estimators in Table 6, the Hausmann specification test is applied in order to select the most appropriate model. The *p*-values obtained do not allow us to reject the null hypothesis of no systemic differences between the coefficients of FE and RE (all the *p*-values are higher than the 5% threshold value). This suggests that the estimates for the RE are appropriate. With regard to the RE, the coefficients of

determination (*adjusted* R^2) are0.44; 0.22 and 0.48 for the Theil, Theilext and Theilint models, respectively, indicating a good quality of adjustment.

Table 6. Baseline results.

Variable	Fixed Effects (FE)			Random Effects (RE)		
	Theil	**Theilext**	**Theilint**	**Theil**	**Theilext**	**Theilint**
Constant	5.229*** (0.429)	4.103*** (1.514)	0.782 (1.679)	5.207 (0.502)	3.032** (1.184)	1.452 (1.322)
Transp	0.081*** (0.015)	0.051*** (0.017)	0.023 (0.018)	0.065 (0.018)	0.051*** (0.014)	0.019 (0.015)
Elect	-0.001* (0.000)	0.000 (0.000)	-0.001 (0.000)	-0.003 (0.000)	0.001 (0.000)	-0.007** (0.000)
Net	0.025*** (0.006)	-0.001 (0.002)	-0.003 (0.001)	0.023 (0.007)	-0.002 (0.001)	-0.003** (0.001)
Tel	-0.005*** (0.001)	0.005 (0.007)	0.019 (0.007)	-0.004 (0.001)	0.006 (0.005)	0.017*** (0.006)
Rent	0.007** (0.003)	-0.003 (0.003)	0.009 (0.003)	0.007 (0.003)	-0.002 (0.002)	0.008*** (0.003)
Freetrade	-0.049 (0.046)	-0.040 (0.048)	-0.013 (0.053)	-0.051 (0.052)	-0.033 (0.039)	-0.016 (0.042)
Invest	-0.012*** (0.003)	0.007** (0.003)	-0.018 (0.003)	-0.013 (0.003)	0.006*** (0.002)	-0.019*** (0.002)
GDP	0.0001 (0.000)	-0.474** (0.209)	0.548 (0.232)	0.0001 (0.00)	-0.315** (0.153)	0.447*** (0.170)
FDI	-0.008** (0.003)	0.012*** (0.004)	-0.020 (0.004)	-0.007 (0.004)	0.013*** (0.003)	-0.021*** (0.003)
Findev	1.876 (2.193)	-1.782 (2.319)	4.089 (2.572)	1.134 (2.478)	-1.796 (1.895)	3.762* (2.066)
R^2	0.884	0.887	0.914	0.443	0.221	0.480
Adjusted R^2	0.868	0.871	0.902	0.403	0.315	0.442
S.E. of reg	0.296	0.317	0.352	0.308	5.232	0.348
F-statistic	55.70 (0.000)	56.98(0.000)	77.64(0.000)	11.06(0.000)	10.00(0.000)	12.83(0.000)
D–W stat.	1.570	1.186	1.187	1.343	1.150	1.159
Log-likelihood	-20.389	-30.556	-46.085			
Hausman test (Prob.)	0.001 (0.900)	1.625(0.998)	1.481(0.999)			
Observations	150	150	150	150	150	150

Note: Standards errors are in brackets.***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.

However, the FE and RE models may suffer from the issue of serial autocorrelation and heteroscedasticity. This means that the RE estimators are biased and non-consistent. Moreover, the RE model does not account for endogeneity bias. To account for these econometric issues, and for the small sample size, more appropriate estimators are the FMOLS and DOLS.

The results of the FMOLS and DOLS estimates are shown in Table 7 for the overall export concentration and the export concentration index along the extensive and intensive margin equations. The results from the FMOLS and DOLS estimators converge, so we focus our discussion on the FMOLS and DOLS results, which are the preferred results because of their relative advantages for the FE and RE estimators.

The adjusted R-squared of the overall export concentration (Theil), the export concentration along the extensive margin (Theilext) and the export concentration along the intensive margin (Theilint) equations with FMOLS and DOLS estimators vary from the minimum valueof0.88 to the maximum value of 0.89, suggesting a very good adjustment quality in the models.

Concerning the overall export concentration and export concentration along the extensive and intensive models, the estimated coefficients for transport infrastructure have unexpected positive signs. A one-point increase in the transport infrastructure results in increases of 0.083, 0.054 and 0.021, respectively, for the overall export concentration, export concentration along the extensive margin, and the intensive margin with the FMOLS estimator, and increases of 0.070, 0.051 and 0.023, respectively, for the overall export concentration ,the export concentration along the extensive margin, and the intensive margin with the DOLS estimator. These findings seem to contradict those of Canning and Pedroni (2004). However, this does not mean that transport infrastructure should be reduced, but rather that exports are not influenced at all by transport infrastructure.

Transport infrastructure is known as having potentially backward and forward effects on an economy, but their paradoxical effects on export diversification can be due to many reasons. Paved roads are of poor quality and are far below the export diversifying level. These infrastructures are concentrated in urban areas in the ECCAS sub-region. Road infrastructure policies in the ECCAS sub-region give priority to the connection of chief regional capitals to main political and economic capitals rather than facilitating the production and exportation of agricultural goods, which remains the backbone of the majority of ECCAS. Even when these infrastructures were built for the benefit of the economy, they are oriented toward the production and the exportation of a limited number of traditional crops and natural resources. In such a context where the economies also depend on agriculture, which is carried out in rural areas that are disconnected from urban areas, farmers face many difficulties in taking their products to local and international markets. The maintenance of these installed infrastructures is always problematic since there are potholes on many paved roads that hamper their effective use. This results in limited capacity of exporting new products, more even distribution of exports sales across the existing set of exported goods, and export concentration. Also, the poor quality of infrastructure, as pointed out by Mbekeani (2007);Do and Levchenko (2009) and Lawless (2010), results in high transport costs, which is a major impediment to trade competitiveness and sustainable development in most African countries.

A one-point increase in the installed electricity capacity results in an increase of0.001 for the overall export diversification and the export diversification along the intensive margin for both the FMOLS and DOLS estimators. The same increase in the installed electricity capacity results in a 0.001 decrease in the export diversification along the extensive margin in both the FMOLS and DOLS estimators. But these results reveal that the stock of electricity infrastructure is not enough to significantly contribute to diversification in ECCAS. Also, the installed electricity capacity significantly contributes to the export diversification at the intensive margin but reduces the export diversification at the extensive margin.

Access to internet negatively and significantly affects the overall export diversification and the export diversification along intensive margin, but no significant effect was found for the export diversification along the extensive margin. This may be explained by the low rate of adoption of internet use by many small enterprises that dominate the economies of the ECCAS sub-region. These small enterprises have limited access to international markets, therefore limiting the possibility of selling new products. Also, the internet is used more by households than enterprises as an input.

Access to mobile phone contributes to the overall export diversification, but the effects on export diversification along the extensive margin are not significant. A one-point increase in internet access contributes to increases of0.004, 0.001 and 0.003, respectively, in the overall export diversification, the export diversification along the extensive margin, and the intensive margin with the FMOLS estimator, and increases of 0.005, 0.001 and 0.003, respectively in the overall export diversification, the export diversification along the extensive margin and the intensive margin with the DOLS estimator. This evidence is in line with Giri et al. (2019) andOsakwe et al. (2018) concerning the overall export diversification and the export diversification along the intensive margin. But at the same time, they contradict findings concerning export diversification along the extensive margin(Giri et al., 2019).

Table 7. FMOLS and DOLS estimates of the long-run effects of infrastructure on export diversification.

Variable	FMOLS			DOLS		
	Theil	**Theilext**	**Theilint**	**Theil**	**Theilext**	**Theilint**
Constant	4.106** (0.752)	3.961* (1.036)	3.146* (1.181)	4.250** (0.910)	3.101** (1.491)	-3.858* (1.787)
Transport	0.083*** (0.019)	0.054*** (0.020)	0.021 (0.022)	0.070*** (0.023)	0.051** (0.022)	0.023 (0.025)
Elect	-0.001 (0.001)	0.001 (0.001)	-0.001** (0.001)	-0.001* (0.000)	0.0001 (0.001)	-0.001* (0.001)
Net	0.020* (0.008)	-0.001 (0.008)	0.0205** (0.0093)	0.025*** (0.004)	0.005 (0.009)	0.019* (0.010)
Tel	-0.004** (0.002)	-0.001 (0.002)	-0.003 (0.002)	-0.005** (0.001)	-0.001 (0.002)	-0.003 (0.002)
Rent	0.009** (0.004)	-0.002 (0.004)	0.011** (0.005)	0.006*** (0.002)	-0.003 (0.004)	0.009** (0.005)
Freetrade	-0.073 (0.053)	-0.070 (0.057)	-0.0001 (0.063)	-0.041 (0.043)	-0.040 (0.062)	-0.013 (0.069)
Invest	-0.010* (0.004)	0.008** (0.004)	-0.018*** (0.004)	-0.011*** (0.003)	0.007* (0.004)	-0.019*** (0.005)
GDP	0.037 (0.254)	-0.244 (0.271)	0.233 (0.303)	0.335* (0.181)	-0.474* (0.270)	0.548* (0.303)
FDI	-0.011** (0.005)	0.013** (0.005)	-0.024*** (0.006)	-0.008** (0.004)	0.012** (0.005)	-0.021*** (0.006)
Findev	2.274 (2.652)	-2.304 (2.834)	4.981* (3.161)	1.028 (1.699)	-1.782 (2.991)	4.090 (3.356)
R-squared	0.889	0.896	0.889	0.881	0.887	0.884
Adjusted R-squared	0.873	0.880	0.873	0.865	0.871	0.868
S.E. of regression	0.296	0.303	0.296	0.301	0.317	0.297
Durbin–Watson stat	1.508	1.191	1.508	1.562	1.186	1.577
Sum squared resid.	10.611	11.095	10.611	11.852	13.199	11.539
Long-run variance	0.101	0.115	0.101	0.108	0.146	0.108
Observations	150	150	150	150	150	150

Note: Standards errors are in brackets; ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.

The hypothesis of the curse of natural resources is confirmed, especially for the overall export diversification and export diversification along the intensive margin. In fact, a one-percentage-point increase in the natural resource rent results in decreases of 0.009 and 0.011, respectively, in the overall export diversification and the export diversification along the intensive margin with the FMOLS estimator, and 0.006 and 0.009 with the DOLS estimator. The natural resource rent contributes, but not significantly, to export diversification along the extensive margin. A one-point increase in natural resource rent results in increases of 0.002 and 0.003 in the export diversification along the extensive margin with both the FMOLS and DOLS estimators, respectively. This last result contradicts the findings of Giri et al. (2019),who found that its effect on the export concentration along the extensive margin is positive. Trade freedom policies positively and significantly contribute to export diversification in ECCAS. A one-point increase in trade freedom results in increases of 0.073, 0.070 and 0.0001, respectively, in the overall export diversification and the export diversification along the extensive and intensive margins with the FMOLS estimator, and increases of 0.041, 0.040 and 0.013, respectively, for the overall export diversification and export diversification along the extensive and the intensive margins with the DOLS estimator. These results are in line with the conclusions of Fonchamnyo and Akame (2017) but contradict those of Lall (1995) and Agosin et al. (2012),who found that trade openness globally induces specialization and not export diversification.

Liberalizing investments contribute positively and significantly to the overall export diversification and the export diversification along the intensive margin, while it contributes significantly and negatively to the export diversification along the extensive margin. In fact. a one-point increase in investment freedom results in increases of0.010 and 0.018,respectively, in the overall export diversification and export diversification along intensive margin with the FMOLS estimator, and increases of 0.011 and 0.019, respectively, in the overall export diversification and the export diversification along the intensive margin with the DOLS estimator. But this same

point increase leads to decreases of 0.008 and 0.007 in the export diversification along the extensive margin with the FMOLS and DOLS estimators, respectively. The level of development as measured by GDP per capita contributes to the export concentration in ECCAS. Evidence suggests that a one-point increase in GDP per capita results in increases of 0.037 and 0.023, respectively, for the overall export concentration and the export concentration along the intensive margin with the FMOLS estimator, and 0.335 and 0.548withthe DOLS estimator. GDP per capita contributes, but not significantly, to export diversification along the extensive margin. A one-point increase in GDP per capita results in decreases of 0.244 and 0.474 in the export concentration along the extensive margin with the FMOLS and DOLS estimators, respectively. These findings contradict those of Cadot et al. (2011) for diversification across the export lines or along the extensive margin. FDI positively and significantly affects the overall export diversification and the export diversification along the intensive margin, while its effect on export diversification along the extensive margin is negative and significant. A one-percentage-point increase in FDI results in increases of0.011 and 0.024, respectively, in the overall export diversification and the export diversification along the intensive margin with the FMOLS estimator, and increases of 0.008 and 0.021, respectively, in the overall export diversification and the export diversification along the intensive margin with the DOLS estimator. But this same percentage point increase leads to decreases of 0.013 and 0.012 in the export diversification along the extensive margin with the FMOLS and DOLS estimators, respectively. This finding is supported by those of Gourdon (2009). Though financial development in ECCAS is not significantly associated with the overall export diversification and export diversification along the intensive margin, it is positively associated with the export diversification along the extensive margin. A one-point increase in financial development results in decreases of 2.274 and 4.981, respectively, for the overall export diversification and the export diversification along the intensive margin with the FMOLS estimator, and 1.028 and 4.09 with the DOLS estimator.

Table 8. Robustness analysis results.

Variable	FE	RE	FMOLS	DOLS
Constant	0.991** (0.278)	0.823** (0.137)	-0.035* (0.013)	-0.025** (0.013)
Transport	-0.001 (0.003)	-0.001 (0.003)	0.004 (0.004)	-0.001 (0.004)
Elect	0.000*** (0.000)	0.000 (0.000)	-0.0001*** (0.000)	-0.000** (0.000)
Net	0.003 (0.001)	0.823*** (0.137)	0.0017 (0.002)	0.003 (0.002)
Tel	-0.001** (0.000)	-0.0008** (0.000)	-0.0004*** (0.000)	-0.001** (0.000)
Rent	0.002*** (0.001)	0.001** (0.000)	0.001*** (0.001)	0.002*** (0.001)
Freetrade	0.021** (0.009)	0.024*** (0.009)	-0.011*** (0.012)	-0.021* (0.012)
Invest	0.000 (0.001)	0.0001 (0.000)	0.0008*** (0.001)	0.0001** (0.001)
GDP	-0.046 (0.038)	-0.021 (0.017)	0.055 (0.055)	-0.046 (0.052)
FDI	0.002*** (0.001)	-0.002** (0.001)	-0.001*** (0.001)	-0.002** (0.001)
Findev	0.234 (0.426)	-0.584 (0.397)	0.578 (0.578)	0.234 (0.575)
R-squared	0.599	0.002	0.583	0.599
Adjusted R-squared	0.544	0.247	0.521	0.544
S.E. of regression	0.058	0.193	0.061	0.058
Durbin–Watson stat	1.176	0.571	1.197	1.176
Hausman test (Prob.)	0.001 (0.01)			
Observations	150	150	150	150

Note: Standard errors are in brackets;***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.

Financial development contributes, but not significantly, to export diversification along the extensive margin. These findings contradict those of Giri et al. (2019),who used credit to the private sector as a financial development indicator in emerging market and developing economies (EMDEs). Thus, the financial system needs to be developed much more in terms of the outreach in order to increase the product or export lines in ECCAS' economies.

4.3. Robustness Check

In order to confirm the effects of infrastructure and other control variables on export diversification, a robustness check was carried out by replacing the Theil overall concentration index by the HHI of export as a dependent variable. The coefficients were estimated while still using the FMOLS and DOLS estimators. The results presented in Table 8 show that the conclusions remain almost the same regarding the effects of infrastructure on export diversification. Changing the dependent variable reveals that the FE estimator is more appropriate. Also, transport negatively affects export concentration with the FE, RE and DOLS estimators, while the signs of coefficients associated **to** GDP and investment freedom change with FE estimator.

5. CONCLUSION

In this paper, we investigated the effect of infrastructure, namely transport infrastructure, installed electricity capacity, and internet and mobile phone use, on export diversification over the period from 2000–2016. For this purpose, the overall export concentration index and its two components—export concentration along the extensive and intensive margins—were used as the dependent variables.

Electricity infrastructure is positively associated with the overall export diversification and the export diversification along the intensive margin, while it is negatively associated with the export diversification along the extensive margin. Transport infrastructure negatively and significantly contributes to the overall export diversification and export diversification along both margins. There appears to be little evidence that internet infrastructure contributes to the overall export diversification, while telephone infrastructure positively impacts export diversification. Globally, infrastructure is provided below the growth maximizing export diversifying level in ECCAS. Therefore, the stock of available infrastructure needs to be increased and improved.

The natural resource rent is negatively associated with the export diversification and confirms the hypothesis of the curse of natural resource applied to the export diversification in the ECCAS sub-region. FDI contributes positively and significantly to the overall export diversification and the export diversification along the intensive margin, while it contributes significantly and negatively to the export diversification along the extensive margin. The real per capita income contributes to the export concentration in ECCAS. The financial development is positively, but not significantly, associated with the overall export diversification and the export diversification along the intensive margin, while liberalizing investments contributes positively and significantly to the overall export diversification and export diversification along the intensive margin. Trade liberalization policies positively and significantly contribute to the export diversification in ECCAS.

The policy implications of these results are that the stock of infrastructure should be increased quantitatively and qualitatively. The spatial distribution of infrastructure must depend on their capacity to produce a variety of tradable goods and services than improving living conditions of urban populations. In this line, and given the dependence of ECCAS economies on agriculture, priority in terms of infrastructure should be given to rural areas where production activities are carried out. Also, the maintenance of the installed infrastructure is more than necessary since ongoing power shortages and potholes on many paved roads hamper the effective use of these infrastructures. Finally, the export diversification policy in ECCAS will prioritize the introduction of new export categories (extensive margin of exports). Investment in infrastructure may be accompanied by trade and investment liberalization and financial development.

Funding: This study received no specific financial support.
Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study.

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Appendix 1. Data descriptions and sources.

Codes	Variable	Explanation	Sign	Source
Theil	Theil's index of export concentration	This is a measure of export concentration calculated using Theil's formulae (products are classified according to the Harmonized System at the 6-digit level HS6).	-	IMF database
Theilext	Theil's index of export concentration at extensive margin	Measures the introduction of new export categories in a country's export mix.	-	
Theilint	Theil's index of export concentration at intensive margin	This evaluates the equality of export values across export lines.	-	
Findev	Financial development index	This is an index calculated using the weighted average of the financial intermediation index and stock exchange market development index.	-	
Concent	Herfindahl–Hirschman Index of export concentration	This is a measure of export concentration calculated using Herfindahl–Hirschman formulae (products are classified according to the Harmonized System at the 4-digit level – HS4).	-	WDI online database
Elect	Installed electricity capacity	It is the total installed electricity capacity in kw per 100 inhabitant	-	
Tel	Telephone access	This is the total mobile phone subscriptions per 100 inhabitants.	-	
Net	Internet access	Net is the number of internet users per 100 inhabitants		
GDPC	Gross domestic product per capita	GDP is the log value of per capita for gross domestic product. Data are in constant 2010 US dollars.	+/-	
Transp	Transport composite index	This is the weighted average of total paved roads in km per 10,000 inhabitants and the total road network in km per km2 of exploitable land area.	-	African Development Bank
Rent	Natural resource rent	Natural resource rent is the difference between the value of natural resource production at world prices and total costs of production expressed in percentage of GDP.	+/-	Torell et al. (2018)
Freetrade	Index of freedom to trade internationally	The index is calculated using the following indicators: taxes on international trade, regulatory trade barriers, actual size of the trade sector compared to the expected size, the difference between the official exchange rate and the black-market rate, and international capital market controls. It scrutinizes each country's policies on foreign investment.	-	
Invest	Investment freedom	This determines a country's overall investment climate. The country's investment freedom ranges between 0 and 100, where 100 represents the maximum degree of investment freedom.	-	
FDI	Foreign Direct Investment	This is the net inflow of Foreign Direct Investment in US dollars in percentage of GDP.	-	
Global	Index of globalization	Index of globalization is the weighted average of economic globalization, social globalization and political globalization. Most weight has been given to economic followed by social globalization.	-	