Spatial diffusion of agricultural production in WAEMU: Does climate change play a role?

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Abstract
The objective of this article is to analyze spatial diffusion of agricultural production in WAEMU and to see if climate change plays a role. We used recent data from the union over the period 1996 - 2016. Results reveal from a spatial autoregressive model that agricultural production spreads spatially positively in the union, and it is beneficial to the whole union. Climate change and climate policies could play an important role, as a country can copy climate policy of another country of the union to improve its agricultural production through spatial spillover effects. Improvement of climate and agricultural policies of countries must be beneficial to agricultural development of the whole area.

Keywords: Spatial diffusion, agricultural production, climate change, WAEMU.

JEL Classification: Q18.

Résumé
L'objectif de notre article est d'analyser la diffusion spatiale de la production agricole dans l'UEMOA et de voir si le changement climatique y joue un rôle. Nous avons utilisé les données récentes de l'union sur la période 1996 - 2016. Les résultats révèlent à partir d'un modèle autorégressif spatial que la production agricole se diffuse spatialement positivement dans l'union, ce qui est avantageux à toute l'union. Le changement climatique et les politiques climatiques pourraient y jouer un rôle important, un pays pouvant copier la politique climatique d'un autre pays de l'union pour améliorer sa production agricole grâce aux effets de débordement spatial. L'amélioration des politiques climatiques et agricoles des pays de l'union doit être bénéfique au développement agricole de toute la zone.

Mots clés : Diffusion spatiale, production agricole, changement climatique, UEMOA.

Classification JEL: Q18.

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Introduction

The economic growth of the West African Economic and Monetary Union (WAEMU) is not declining with a rate of 6.8% in the year 2018. While activity is mainly driven by the tertiary sector, food crops and cash crops well above the average of the previous five seasons and the food and beverage industry is up 14.5%, according to the latest report on monetary policy in WAEMU of the Central Bank of West Africa (BCEAO).

Thanks to favorable rainfall during the 2018-2019 crop year, food production increased by 8.3% in 2018-2019 in the WAEMU zone to reach nearly 65 million tonnes (Mt), with an increase of nearly 11% of cereals and 15.4% of other crops, mainly horticulture. Compared to the average of the previous five years, the 2018-2019 crop year crops are up 19.5%. At the level of cash crops, all crops are growing, with the exception of cocoa, with for some, like coffee, substantial increases. Coffee production climbed 167.3% to 137,726 tonnes, but the BCEAO is returning to normal after the weak 2017-2018 season following the heavy rains. Cotton production gained 3.1% at 2.509 Mt while groundnut production increased by 3.7% to 3.302 Mt. Among other growing crops, cashew nuts (+ 4%) to 1.186 Mt and rubber (+ 5.8%) to 613,900 tonnes. On the other hand, cocoa production would fall by 3.7% to 1,969 Mt but remain above the average of these five previous seasons. On the other hand, while crops are growing, the prices of the main agricultural raw materials exported by WAEMU have been less favorable. The WAEMU industrial production index rose 5.4% in 2018 thanks to the improvement in manufacturing industries (+ 10.2%) driven by chemicals (+ 26.2%) but also food and beverages (+ 14.5%).

The current economic realities emphasize the existence of spatial interactions in the economic and social phenomena observed between countries, mainly when these countries are geographically contiguous, closed to each other or belong to the same union (Anselin, 1988, Julie Le Gallo, 2002, Tobler, 1979). An economic phenomenon occurring in one country may well affect the other country closed to it. Membership of the same union thus raises relevance of spatial diffusion of many economic phenomena between WAEMU countries, especially that of agricultural production. We ask ourselves whether and how agricultural production spreads spatially between countries of the union, given the free movement of goods and services and individuals, the international exchanges between them and the economic cooperation that connects them. Does geographical proximity of countries, geographical contiguity of countries, membership of the same monetary union, similar adoption and copies of policies related to climate change explain this spatial diffusion of agricultural production in the union if it really exists?

Spatial interaction is today a very relevant and insightful central economic issue of economic analysis.

This article explores the spatial diffusion of agricultural production in WAEMU countries.

The interest of the research is therefore to analyze from a spatial autoregressive model a new economic phenomenon: "the spatial interaction of agricultural production in WAEMU". The work thus extends explicitly by also analyzing the form of spatial diffusion retained in the union. A second interest is to appreciate the economic cooperation between countries, the policy of free movement of goods and services and individuals between them, this belonging to the same union, climate change in the union and the policies related to this climate change. The analysis should normally awaken the minds of economic decision-makers, provide relevant policy perspectives to economic emergence of the union and policies to promote better agricultural progress, when we determine the form of spatial diffusion.

Indeed, if we detect that agricultural production is spreading positively in the union, that is agricultural production of a country remains favorable to agricultural production of another country of the union, we can conclude that economic cooperation, free trade, copies of agricultural policies and policies related to climate change are currently very advantageous for the union, and our countries must always grow in agriculture, always develop good economic cooperation to start a satisfactory agricultural development of the whole area. If not, it will be interesting to provide best recommendations for a better economic emergence of the union.

WAEMU countries belong to the same union and are close. They can thus copy agricultural policies and climate change policies to improve their agricultural production, as they often develop similar policies. Copies of climate change policies may then explain this spatial diffusion of agricultural production in the union.

Our article is organized in three sections. A first section presents the review of the literature and a second section focuses on empirical analysis. The conclusion and prospects for economic policies are presented in the third section.

1. Review of literature

1.1. Definition and history of spatial diffusion

Historically, it was Cliff and Ord (1973), after a series of papers in the late sixties and early seventies, who produce a book summarizing spatial statistics and econometrics. After this initial phase of recognition, the late 1970s and early 1980s were characterized by the refinement of Cliff and Ord's original framework of analysis and more particularly by the development of the theory of estimation and testing (Ord , 1975, Anselin, 1988) (Le Gallo, 2002).

According to Anselin and Bera (1998), spatial autocorrelation can be defined in a general way as the correspondence between the similarity of values taken by a variable of interest and the proximity of the spatial units where these same values are observed. More precisely, it reflects the existence of a functional relation between the observations made at the level of the different localizations of the space studied. Tobler (1979) said that "everything is connected to everything and closer things are more". This reflects that in economic phenomena, there are indeed spatial interactions between them essentially when localities studied are closer. Spatial diffusion therefore refers to the fact that an economic phenomenon occurring in one country or locality can have a significant impact on another country or another locality. This is the case, for example, with the spatial diffusion of agricultural growth between countries that will, for example, try to develop similar economic policies to support their agricultural growth (for example, the same agricultural policy or free movement of goods (including intermediate goods of production), services and individuals to promote growth as the case of WAEMU countries).

This article attempts to analyze the spatial diffusion of agricultural production in WAEMU from a spatial autoregressive model. But before this empirical analysis, it is important to present what literature tells us about the process of spatial diffusion and some spatial effects.

1.2. Spatial effects and some empirical studies

Economic realities always emphasize that there are often spatial interactions in economic phenomena, especially when countries studied are closer, neighbors or belong to the same economic union (Tobler, 1979).

Empirically, growth performance is probably not insensitive to the location of countries, even if the economic literature has been very little inspired by questions from consideration of space. Recently (although the economic literature is weak), empirical studies have been proposed to explicitly integrate effects of space on country growth (Ertur, Le Gallo and Baumont, 2005; Conley and Ligon, 2002). Results obtained from this work have well underlined existence of spatial interactions in economic growth of countries for these authors. Other authors have also discussed the spatial diffusion of growth in countries. Ivanova (2012), by exploring spatial data of Russian regional economies, shows that growth spreads spatially positively in these regions. Similarly, Niang (2010) analyzing the spatial convergence of African regions shows a significant positive relationship between them. The same studies of spatial interactions were carried out by Le Gallo and Dall'erba (2005), then by Ertur and Thiaw (2005) from a spatial autoregressive model on developed and developing regions. Results of different studies have highlighted existence of spatial interactions in growth phenomenon of these countries. Consideration of spatial effects is motivated by the fact that there are a large number of factors such as sub-regional integration effects, inter-regional migrations, spatial spillover effects which can be the cause of strong interdependencies between economies. In this case, observations are made by processes that link the localities and that can lead to a particular organization of activities in space (Le Gallo and Dall'erba, 2005).

From Romer growth model (1986), we analyze in the following section the current regional spatial diffusion of agricultural production in WAEMU countries.

2. Empirical analysis

2.1. Basic model

The objective of this paper is to analyze spatial distribution of agricultural production in WAEMU countries, taking into account effect of other countries in the same zone with which a country shares economic relations, that is, the spatial spillover effect. For example, agricultural production in Benin can also affect agricultural production in Togo, etc., and vice versa, thanks to the effects of copying policies, and since these countries are closer, belonging to the same economic and monetary union, sharing individuals, goods and services and economic relations, and having similar development policies.

Taking into account spatial effect is a step forward and increases our study. We analyze whether agricultural production in a WAEMU country leads to agricultural production in another country of the union thanks to spatial spillover effects and spatial externalities produced. These spatial spillover effects could also be explained by copies of climate change policies. If a country improves its climate policy to have more agricultural production, another country of the union can copy the policy to also have more agricultural production at home. On the other hand, better climate with better rainfall in the union, as assessed in recent years, can also be at the origin of a better agricultural production in those countries.

In order to take better account of the effects related to these spatial externalities, we will use a spatial autoregressive model which makes it possible to explain the spatial diffusion of agricultural production between countries.
Our spatial autoregressive model that analyzes the spatial distribution of agricultural production among WAEMU countries can be written in general as follows:

Equation 1

$$y = \text{ª}(I_T \otimes W_N)y + X \quad + u$$

Where y is the $NT \times 1$ vector of the observations of the dependent variable, X a $NT \times k$ matrix of observations of the k model explanatory variables, I_T the dimention T identity matrix, W_N the $N \times N$ weight matrix having on its diagonal the value 0 (according to the configuration standards of weight matrix), and ª the spatial parameter. The noise vector is the sum of two terms:

Equation 2

$$u = (i_T \otimes I_N)\text{«} + \text{£}$$

Where i_T is a $T \times 1$ vector composed of the value 1, I_N an $N \times N$ identity matrix, « a vector of specific effects (non spatially autocorrelated), and £ a vector of spatially autocorrelated errors on the following spatial autoregressive process:

Equation 3

$$\text{£} = \text{°}(I_T \otimes W_N)\text{£} + \text{³}$$

With ° ($|\text{°}| < 1$) the spatial autoregressive parameter on the error, W_N the $N \times N$ weight matrix, $\text{³}_{it} \rightarrow IID(0, \pm^2_{\text{³}})$ and $\text{£}_{it} \rightarrow IID(0, \pm^2_{\text{£}})$.
In the panel literature, specific effects can be treated as fixed or random effects. Implementation of maximum likelihood or generalized method of moments on the spatial model with random effects and on the fixed effects model makes it possible to obtain efficient results, since in spatial regression, ordinary least squares become very inefficient. Apart from presence of spatial dependence on the dependent variable and / or on error, one can also have spatial dependence on specific effects and an autocorrelation of the error (Baltagi et al., 2009).
For all cases of spatial interactions, Baltagi, Song and Koh (2003), then Baltagi, Song, Jung, and Koh (2007) provide consistency and better specification tests of spatial model estimated when squeezing a spatial interaction in economic phenomenon studied.
In order to normalize the effect of weight matrices and to have the sum of each row of matrices equal to 1, we will use standardized weight matrices according to standardization in spatial econometric analysis (line-standardization) which is in the following form: $W_{ij}\ s\tan dardised = \frac{w_{ij}}{\sum_i w_{ij}}$ (line i and column j) (Le Gallo, 2002). All weight matrices also have zero diagonal entries to capture exactly average influence of other countries j on country i (this simply means that $W_{ij} = 0$ if i = j). Three weighting matrices are used in our study: (i) the geographic contiguity matrix of the WAEMU countries (W1), which captures spatial effect between

neighboring countries; (ii) matrix of inverse of the geographical distance between countries of the union (W2) which makes it possible to capture spatial effect taking into account distance between countries and (iii) matrix of the square of the inverse of the geographical distance between countries (W3) that captures the spatial effect by taking into account distance squared between countries to see magnitude of the effect of distance to explain spatial externalities.
Matrices are represented as follows:

$$W_1 = \begin{cases} 1 \; if \;\; countries \; are \; geographically \; contiguous \; and \; if \;\; i \neq j \\ 0 \; if \;\; countries \; are \; not \; geographically \; contiguous \; and \; if \;\; i = j \end{cases}$$

$$W_2 = \begin{cases} \dfrac{1}{d_{ij}} \; if \;\; countries \; are \; dis\tan t \;\; from \; each \; other \; and \; if \;\; i \neq j \\ 0 \; if \;\; i = j \end{cases}$$

$$W_3 = \begin{cases} \dfrac{1}{d_{ij}^2} \; if \;\; countries \; are \; dis\tan t \;\; from \; each \; other \; and \; if \;\; i \neq j \\ 0 \; if \;\; i = j \end{cases}$$

Our dependent variable is the logarithm of agricultural value added (denoted LVAAGRI). The explanatory variables in the model are logarithm of gross capital formation (denoted LGCF), logarithm of the labor force (represented by those aged 16 and over) (noted LLABFORCE), foreign trade represented by the sum of exports and imports as a share of GDP (TRADE), the log of government expenditure (noted LG), inflation captured by GDP deflator (noted INFLATION).
To better describe this model of spatial distribution of agricultural production in WAEMU countries, it is important to first carry out the pre-estimation spatial tests in order to retain the best specification of the model.
For these spatial tests, the Baltagi et al. (2007) analysis of the spatial and serial dependence of errors under random effects and the Baltagi et al. (2003) analysis of the real presence of random effects in model to be estimated as well as Hausman spatial test of choice between fixed and random effects in the model, which make it possible to retain the best form of spatial diffusion and the best econometric specification of the model, provide following results:

Table 1: Spatial pre-estimation tests

Tests	LM value			p-value		
	W_1	W_2	W_3	W_1	W_2	W_3
Baltagi & al. (2007) tests						
Ha: Spatial dependence in error terms, sub random effects and serial correlation (test C.1)						
Response (df = 1)	0.0068781	0.0085261	0.0043029	0.9339	0.9264	0.9477
Ha: Serial correlation in error terms, sub random effects and spatial dependence (test C.2)						
Response (df = 1)	59.586	59.586	72.412	1.17e-14	1.17e-14	< 2.2e-16
Ha: Random effects or serial correlation or spatial dependence in error terms (test J)						
Response (df = 3)	685.76	686.06	687.56	< 2.2e-16	< 2.2e-16	< 2.2e-16
Baltagi & al. (2003) tests						
Ha: Presence of random effects						
Response	25.969	25.969	25.969	< 2.2e-16	< 2.2e-16	< 2.2e-16
Hausman spatial test						
Ha: One model (with random effect or fixed effects) is inconsistent						
	Chi2 value			p-value		
Response (df = 5)	0.84382	0.46563	1.529	0.9742	0.9933	0.9097

Note: W1, W2 and W3 correspond respectively to the geographic contiguity matrix, matrix of inverse of the geographical distance between countries and matrix of square of the inverse of the geographical distance, all standardized.
Source: Calculation of authors from data.

From tests of Baltagi et al. (2007), there is no spatial dependence in error term with a serial dependence (test C.1 and C.2). And because of acceptance of hypothesis of presence of random effects in the model to be tested by Baltagi et al. (2003), we retain the random effects in the model, and the best specification of the model is the RESAMSC (Random Effetcs Spatial Autoregressive Model with Serial Corrrelation).
Our model tested with consistency is specified as follows:

Equation 4

$$y = ª(I_T \otimes W_N)y + (i_T \otimes I_N)« + X \quad + £$$

$$£_{it} = \cdot £_{it-1} + e_{it}$$

2.2. Data and estimation methods

For our work, we used recent data from World Bank (2019) over the period 1996 - 2016. Mostly data used come from World Bank's World Development Indicators (WDI) (2019).

Descriptive statistics of variables can be presented as follows:

Table 2: Descriptive statistics

Variable	Observation	Mean	Std. deviation	Minimum	Maximum	Source
LVAAGRI	168	27.13107	0.7826242	25.32049	28.73897	WDI, 2019
LGCF	168	26.78605	1.241605	23.38632	28.97376	WDI, 2019
LLABFORCE	168	15.31973	0.7518495	13.34241	16.30192	WDI, 2019
TRADE	168	0.6287632	0.1844245	0.3073252	1.250278	WDI, 2019
LG	168	26.62703	0.9718752	24.44711	28.32049	WDI, 2019
INFLATION	168	0.0376592	0.0804821	-0.1073023	0.8089967	WDI, 2019

Source: Calculation of authors from data.

For estimation method, we used maximum likelihood method with random effects for the model, which analyzes the spatial diffusion of agricultural production in WAEMU countries. As ordinary least squares cannot give consistent results in spatial analysis, maximum likelihood method provides robust estimations.

2.3. Results

Results of estimation are presented in the following table.

Table 3: Results of regression from Equation 4 - Dependent Variable: LVAAGRI

Variables	Maximum likelihood		
	W_1	W_2	W_3
a	0.537704***	0.482187***	0.388665***
	(9.4661)	(7.5835)	(6.4731)
Constant	3.866102***	3.212639***	4.120504***
	(4.0279)	(3.0609)	(3.8871)
LGCF	0.158000***	0.184247***	0.186039***
	(6.6758)	(7.1276)	(6.9263)
LLABFORCE	0.555781***	0.654341***	0.753285***
	(8.8165)	(9.4940)	(10.7801)
TRADE	0.360392***	0.423640***	0.398501***
	(3.1429)	(3.3812)	(3.0896)
LG	0.145903***	0.143957***	0.140459***
	(6.7995)	(6.1425)	(5.7644)
INFLATION	-0.149230	-0.095479	-0.163494
	(-1.1722)	(-0.6867)	(-1.1308)
Obs	168	168	168
Adj. R^2	51.37%	52.89%	51.47%

*, ** and *** represent respectively thresholds of significance at 10%, 5% and 1%. Z-statistics are in parentheses.

Source: Estimations and calculations of authors from data.

Results of analysis (Table 4) show that there is significant spatial diffusion of agricultural production in WAEMU, whether countries are neighboring or distant (Coefficient a). Agricultural production in one country of the union leads to agricultural production in another country of the union. These spatial externalities are well explained by copies of policies between countries. It

means if a country tries to grow in agriculture, another country of the union copies this policy and also tries to grow at home.
This advantageous spatial diffusion of agricultural production in the union can also be explained by current improvement of the climate and the rainfall in the union. Also, this spatial diffusion can be explained by copies of climate policies. If a country develops a better climate change policy to improve agricultural production, another country of the union copies this policy to improve its agricultural production. Agricultural production and agricultural policy developed by WAEMU countries become thus advantageous factors for economic development.

Conclusion and prospects for economic policies

In this article, we analyzed spatial diffusion of agricultural production in WAEMU countries. After theoretical background, results of studies show that agricultural production spreads spatially positively in the union, whether countries are neighbors or distant.

In terms of prospects for economic policies, it is important that our countries develop better agricultural policies at home to have better agricultural production not only at home but throughout the union from spatial spillover effects. Each country must also always grow in agriculture, improve its policy related to climate change so that by copies of policy, other countries of the union can also benefit from a country's policy to grow in agriculture, and this should be beneficial for the whole union in terms of agricultural development, thanks to positive spatial externalities produced.

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Appendix

Appendix 1 : Matrix of correlations

Table 4: Matrix of correlations

	LVAAGRI	LGCF	LLABFORCE	TRADE	LG	INFLATION
LVAAGRI	1.0000					
LGCF	0.7653	1.0000				
LLABFORCE	0.9189	0.8192	1.0000			
TRADE	0.2146	0.1352	0.1570	1.0000		
LG	0.5729	0.8187	0.6290	-0.1055	1.0000	
INFLATION	-0.2997	-0.1856	-0.3477	-0.0534	-0.0822	1.0000

Source: Calculation of authors from data.