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Climate Change and Economic Growth in Niger: A long term analysis via the agriculture channel

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ABSTRACT: The objective of this paper is to analyse the effect of climate change on economic growth through the agriculture channel in Niger. The method of analysis used is the autoregressive lag model (ARDL). From the results, temperature does not appear to affect long term economic growth through the agricultural production channel. This can be explained by the adaptation measures taken by farmers, which are transmitted from generation to generation.

KEYWORDS: Temperature, Economic Growth, Agricultural production, Long term, Niger.

1 INTRODUCTION

Niger is a country in West Africa and part of the Sahel region. Currently populated by 22 million people, it is one of the fastest growing countries in the world, with an annual growth rate of 3.8% [1]. The majority of the population lives in the southern cities, the most populous being Niamey, followed by Maradi, Zinder and Tahoua. With a real GDP per capita of USD 404, Niger is one of the poorest countries in the world and is a Least Developed Country (LDC) [1]. Its economy is dominated by the agricultural sector, which contributes to 39.2% of its GDP, followed by the services sector (38.1%) and the industrial sector (15.5%) [2]. Food crop production is dominated by cereals such as millet and sorghum [3]. Onions and cowpeas are the main cash crops, with Niger being the second largest producer of cowpeas in West Africa after Nigeria [4]. Other cash crops include groundnuts, sesame and edible nutsedge [4], [5]. In 2017, oilseeds accounted for 88% of Niger's agricultural exports while rice was the main agricultural import, accounting for 5.8% of total imports [6]. More than 80% of Niger's population is employed in the agricultural sector, on which they depend heavily for their livelihoods and food security [7].

In recent years, climate change seems to be changing the face of Niger's economy and the living conditions of its people. The air temperature in Niger is expected to increase by 2.0°C to 4.6°C by 2080 compared to the year 1876, depending on different GHG emission scenarios [8]. Compared to pre-industrial levels, the median temperature increase of the climate models in Niger reaches about 2.1°C in 2030, 2.5°C in 2050 and 2.6°C in 2080 under the emission reduction scenario. For the medium-to-high emissions scenario, the median of the climate model temperature increases is 2.1°C in 2030, 2.7°C in 2050 and 3.7°C in 2080. In parallel with the increase in average annual temperatures, the number of very hot days per year (days with a maximum temperature of more than 35 °C) is expected to increase sharply and with a high degree of certainty, particularly in the southwest of the country [8]. Under the medium to high emissions scenario, the median of the multi-model ensemble (averaged over the whole country) predicts 16 more hot days per year in 2030 compared to 2000, 27 days in 2050 and 40 days in 2080. In some parts of the country, particularly in the southwest, this equates to about 300 hot days per year by 2080.

Smallholder farmers in Niger also face uncertainty and variability in weather conditions as a result of climate change [9]. As their crops are predominantly rainfed, yields are highly dependent on the availability of rainwater and are sensitive to drought. However, the duration and intensity of the rainy season is increasingly unpredictable and the use of irrigation equipment remains limited [10].

Climate change is also expected to have a significant impact on Niger's infrastructure. In 2019, for example, torrential rains hit Niger during the wet season, causing flooding in several cities that affected 256,000 people (67% in Maradi, Zinder and Agadez regions) and destroyed 22,000 houses [11]. Between 1998 and 2014, a total of 1.6 million people were affected by floods in Niger [12]. Variability in rainfall and climatic conditions could also seriously disrupt hydropower projects in Niger, including the construction of the Kandadji dam on the Niger River. River flood projections are subject to a significant level of uncertainty, largely related to the uncertainty surrounding rainfall projections and their spatial distribution, and hence flood events. While the absolute value of 0.14% is low to begin with, the median of the projections indicates that the exposure of the country's roads to flooding is expected to more than double by mid-century. Although the median of the projections decreases again towards the end of the century, the assumptions are still subject to a significant level of uncertainty.

The high probability range indicates that road exposure to flooding could range from a threefold increase to a twofold decrease by 2080 (from 0.07-0.4% in 2000 to 0.03-1.3% in 2080). Similarly, the median of the projections for urban areas exposed to flooding at least once a year hardly changes, with a high probability range of 0.0-0.3% by 2080. Note that the projections indicate the exposure of roads to river flooding and exclude, for example, their exposure to flooding due to excessive rainfall, a common phenomenon in Niger, mainly due to its dry, impermeable soil and lack of vegetation [12]. GDP exposure to heat waves is projected to increase from about 1.7% in 2000 to 6% or 11% in 2080 [13].

Climate change is also expected to have a significant influence on the ecology and distribution of tropical ecosystems, although the extent, level and direction of these changes are uncertain [14]. It is important to bear in mind that model projections exclude the impacts on biodiversity of human activities such as land use, which have already caused significant biodiversity losses globally and are expected to remain the main contributors in the future [15]. In recent years, Niger's vegetation has been profoundly altered due to population pressure and increasing demand for agricultural land and fuelwood, leading to a deep degradation of much of the country's soil [16].

Climate change also threatens the health and sanitation sector due to the increased frequency of heat waves, floods, droughts and storms. The main health challenges in Niger are morbidity and mortality resulting from vector-borne diseases such as malaria, water-borne diseases related to extreme weather events (floods, etc.) such as diarrhoea and cholera, respiratory diseases, meningitis, measles, injuries and deaths due to extreme weather events, as well as the effects of climate change on food and water supplies, which may increase the risk of malnutrition and hunger [17]. Many of these challenges are expected to be exacerbated by climate change. According to the World Health Organization (WHO), Niger recorded nearly 8 million cases of malaria in 2018 [18]. Climate change is expected to affect the periods of malaria transmission and the geographical range of vector-borne diseases: in Niger, the overall risk of malaria is expected to decrease due to rising temperatures, but some areas may be at greater risk, for example due to more frequent flooding [19], [20]. A study has shown that increases in temperature and low humidity associated with climate change may anticipate the seasonal occurrence of meningitis and lead to a marked increase in the number of meningitis cases [21], [22]. In 2015 alone, 8,500 cases and 573 deaths were reported [23]. Climate change also threatens food security as households in Niger depend on agricultural production for up to 40% of their food consumption [5]. Rising temperatures will lead to an increased frequency of heat waves in Niger and thus an increase in heat-related mortality. The proportion of the population affected by at least one heat wave per year is projected to increase from 1.7% in 2000 to 12% in 2080. In addition, heat-related mortality is likely to increase more than threefold, from 3 to about 10 deaths per 100,000 inhabitants per year by the end of the century compared to 2000 levels, if no measures are taken to adapt to warmer conditions.

Although this issue is relatively recent, it is subject of theoretical complexity. Several studies highlighting the relationship between economic growth and environmental quality have used the Kuznets environmental curve, which, through a bell curve, explains environmental quality by the level of income [24], [25], [26]. However, talking about the effects of climate change on economic growth amounts, on the contrary, to explaining the level of income by the quality of the environment, through, on the one hand, the theory of geographical differentiation, which states that geography or climate directly affects economic growth [27], [28], [29], [30], [31]; and on the other hand through the institutional theory which believes that climate indirectly affects economic growth via the quality of institutions [32], [33], [34], [35], [36], [37].

The present study is part of this second stream of thought, with the perspective of overcoming the limitations of the work of Dell et al [31], which highlighted the effects of climate change on economic growth in developing countries using traditional econometric analyses (OLS).

The objective of this paper is to analyse the effect of climate change on economic growth via agricultural production in Niger. The search for such the objective is justified by the poor economic performance of this country, which some have tried to explain by the presence of insecurity [38], [39]; and by the low level of sub-regional integration [39]. However, the climate variable has been omitted. Climate change also affects economic growth [27], [28], [29], [30], [40], [31]. This article therefore proposes to integrate the climate variable into the explanation of the income level of this country.

The method of analysis adopted in this study is the ARDL, The use of this method is advantageous in that it takes into account simultaneous short and long term relationships, which allows us to better appreciate the evolution of our estimates. The remainder of this article is organised into four sections. In the second section, the data and methodology of the study are presented; in the third section, the different results of our estimates are analysed. Section 4 concludes with some policy suggestions.

2 MATERIAL AND METHODS

The theoretical model adopted for our study is that of Deschênes-Greenstone [42]. This model, although is an extension of the Ricardian approach, attempts not only to correct the problems associated with the specification of errors, but also to control for unobservable characteristics correlated with climate.

The model of analysis is the staggered lag autoregressive (ARDL), developed by [41], which was extended in 2001. The data is from secondary sources and from the World Data Indicator. The study covers the period 1980 to 2016.

If there is a cointegration relationship, then the long-term model and the error correction version of the model to be estimated can be formulated as follows:

$$Y_t = \varphi Y_{t-1} + \beta_j X_{t-1} + \sum \gamma_j \, \Delta Y_{t-j} + \sum \delta_j \, \Delta X_{t-j} + \mu_i + \theta_{rt} + \varepsilon_t \; (1)$$

Where, X is a vector of explanatory variables, Y is the variable to be explained, βj contains information on long-term impacts, ϕj is the error correction term (due to normalisation), and δj incorporates short-term.

The variables used to estimate the model in equation (1) above are derived from the relevant literature both empirically and theoretically on the relationship between climate change and economic growth. Talking about the effects of climate change on economic growth amounts to explaining the level of income by the quality of the environment through, on the one hand, the theory of geographical differenciation, which states that geography or climate directly affects economic growth; and on the other hand through the institutional theory, which believes that climate indirectly affects economic groth via the quality of institutions. Therefore, tableau 1 below presents the description of the variables used.

Table 1. Variables description

Variables	Description
y	GDP per capita growth (% annual)
pop	Population growth (% annual)
inf	Inflation, gdp deflator (% annual)
ouv	External balance of goods and services (% gdp)
fbcf	Gross fixed capital formation (% gdp)
ide	Foreign direct investment, net inflows (% of gdp)
rcer	Agricultural production approximated by grain yields (% of gdp)
inst	Institution
temp	Annual average temperature (°c)
temp_rcer	Is the transition variable, composed of temperature and agricultural

Source: Authors

By introducing our variables in to the model, the model is written as follows:

$$\begin{aligned} lny_t = \alpha_0 &+ \sum \beta_{1i} lny_{t-i} + \sum \beta_{2i} lnpop_{t-i} + \sum \beta_{3i} lninf_{t-i} + \sum \beta_{4i} lnouv_{t-i} + \sum \beta_{5i} lnfbcf_{t-i} \\ &+ \sum \beta_{6i} lnide_{t-i} + \sum \beta_{7i} lnrcer_{t-i} + \sum \beta_{8i} lninst_{t-i} + \sum \beta_{9i} lntemp_{t-i} + \sum \beta_{10i} lntemp\_rcer_{t-i} \\ &+ \sum \beta_{1i} \Delta lny_{t-i} + \sum \beta_{2i} \Delta lnpop_{t-i} + \sum \beta_{3i} \Delta lninf_{t-i} + \sum \beta_{4i} \Delta lnouv_{t-i} + \sum \beta_{5i} \Delta lnfbcf_{t-i} \\ &+ \sum \beta_{6i} \Delta lnide_{t-i} + \sum \beta_{7i} \Delta lnrcer_{t-i} + \sum \beta_{8i} \Delta lninst_{t-i} + \sum \beta_{9i} \Delta lntemp_{t-i} \\ &+ \sum \beta_{10i} \Delta lntemp\_rcer_{t-i} + \delta \, (ECM)_{\,t-1} + \mu_t + \theta_{rt} + \varepsilon_t \; (2) \end{aligned}$$

With:

$$ECM_{t-1} = lny_{t-1} - \alpha_0 + \sum \beta_{1i} lny_{t-i} + \sum \beta_{2i} lnpop_{t-i} + \sum \beta_{3i} lninf_{t-i} + \sum \beta_{4i} lnouv_{t-i} + \sum \beta_{5i} lnfbcf_{t-i} + \sum \beta_{6i} lnide_{t-i} + \sum \beta_{7i} lnrcer_{t-i} + \sum \beta_{8i} lninst_{t-i} + \sum \beta_{9i} lntemp_{t-i} + \sum \beta_{10i} lntemp_{rcer_{t-i}} \ (3)$$

And:

$$-1 \leq ECM_{t-1} \leq 0 \ and \ \delta < 0$$

The absolute value of δ determines how quickly the equilibrium will be established.

In our case, the unrestricted error correction version of the ARDL model can be formulated as follows:

$$\Delta lny_y = \alpha_0 + \sum \beta_{1i} lny_{t-i} + \sum \beta_{2i} lnpop_{t-i} + \sum \beta_{3i} lninf_{t-i} + \sum \beta_{4i} lnouv_{t-i} + \sum \beta_{5i} lnfbcf_{t-i} + \sum \beta_{6i} lnide_{t-i} + \sum \beta_{7i} lnrcer_{t-i} + \sum \beta_{8i} lninst_{t-i} + \sum \beta_{9i} lntemp_{t-i} + \sum \beta_{10i} lntemp\_rcer_{t-i} + \alpha_1 lny_{t-1} + \alpha_2 lnpop_{t-1} + \alpha_3 lninf_{t-1} + \alpha_4 lnouv_{t-1} + \alpha_5 lnfbcf_{t-1} + \alpha_6 lnide_{t-1} + \alpha_7 lnrcer_{t-1} + \alpha_8 lninst_{t-1} + \alpha_9 lntemp_{t-1} + \alpha_{10} lntemp\_rcer_{t-1} + \eta_t \ (4)$$

3 RÉSULTATS AND DISCUSSIONS

This subsection presents and interprets the econometric results. These are: descriptive statistics and correlation table results (3.1.); preliminary tests (3.2.); long-term effects of climate change on economic growth via the agriculture channel (3.3.); and robustness tests (3.4.).

3.1 RESULTS OF THE DESCRIPTIVE STATISTICS AND CORRELATION TABLE

Table 2. Descriptive analysis

Variables	Mean	Max	Min	Std. Dev.	Obs
PIBH	-0.61	7.44	-19.06	4.97	37
TEMP	26.67	29.19	25.15	1.35	37
FBCF	18.91	40.29	6.76	11.51	37
IDE	2.80	16.62	-2.13	4.55	37
INF	3.84	32.71	-5.90	7.18	37
OUV	0.48	0.71	0.32	0.09	37
INST	0.75	8.00	-7.00	6.26	37
POP	2.59	2.86	2.49	0.08	37
RCER	5.95	6.28	6.28	0.19	37
TEMP_RCER	9.32	9.65	9.65	0.20	37

Source: Authors based on WDI data (2016).

From the results of the descriptive analysis, it can be seen that, over the study period, variables such as economic growth, gross fixed capital formation, foreign direct investment, inflation and institutions are the most volatile than temperature, trade openness, population and agricultural production.

Table 3. Correlation table

Correlation Probability	FBCF	IDE	INF	INST	OUV	POP	RCER	TEMP	TEMP_RCER	TPIBH
FBCF	1									
IDE	0.216	1								
INF	-0.152	0.113	1							
INST	-0.49**	0.156	-0.208	1						
OUV	-0.033	0.203	-0.299*	0.66***	1					
POP	0.171	-0.283*	0.344**	-0.86***	-0.84***	1				
RCER	0.092	0.000	-0.075	0.115	0.44**	-0.21	1			
TEMP	-0.6***	-0.130	-0.367**	0.62***	0.417**	-0.58***	0.016	1		
TEMP_RCER	-0.163	0.125	-0.61***	0.702***	0.68***	-0.84***	0.094	0.64***	1	
TPIBH	0.291*	0.370**	0.054	0.142	0.38***	-0.270	0.156	-0.297*	0.082	1

() P value
****: Significative at 1%;*
***: Significative at 5%;*
**: Significative at 10%.*

Source: Authors based on WDI data (2016).

The correlation table shows that the population variable is negative and not significantly correlated with economic growth. The temperature, on the other hand, is negative and significantly correlated with economic growth. The other variables such as; Gross Fixed Capital Formation, Foreign Direct Investment are positive and significantly correlated with economic growth. However, variables such as Inflation, Institutions, Temperature transition variable and Agricultural production are positive and not significantly correlated with economic growth.

3.2 Results Of The Preliminary Tests

The preliminary tests allow us to assess the feasibility of the ARDL method. We will check in turn the unit root test (4.2.1.), the lag number test (4.2.2.), and the cointegration test using the Bound testing approach (4.2.3.).

3.2.1 Results Of The Unit Root Test

From the table below, it can be seen that with the exception of Inflation and Economic growth which are stationary at level, the rest of the variables are stationary in first difference. This approves the study method.

Table 4. ADF unit root test

Variables	Stationnarité à niveau			Stationnarité en différence 1er		
	DFA cal	Proba	Décision	DFA cal	Proba	Décision
FBCF	0.293	0.974	N.S	-4.099	0.003	S
IDE	-1.382	0.580	N.S	-4.811	0.000	S
INF	-5.046	0.000	S			
INST	-2.108	0.242	N.S	-5.576	0.000	S
OUV	-1.953	0.305	N.S	-5.645	0.000	S
TPIBH	-5.772	0.000	S			
TEMP	-2.250	0.193	N.S	-7,356	0.000	S
RCER	-1.271	0.631	N.S	-8.421	0.000	S

Source: Authors based on WDI data (2016)

3.2.2 Determining The Number Of Delays

The table below shows twenty best models according to the Schwarz information criterion, the ARDL model (1, 2, 0, 1, 0.1) corresponds to the smallest SIC value.

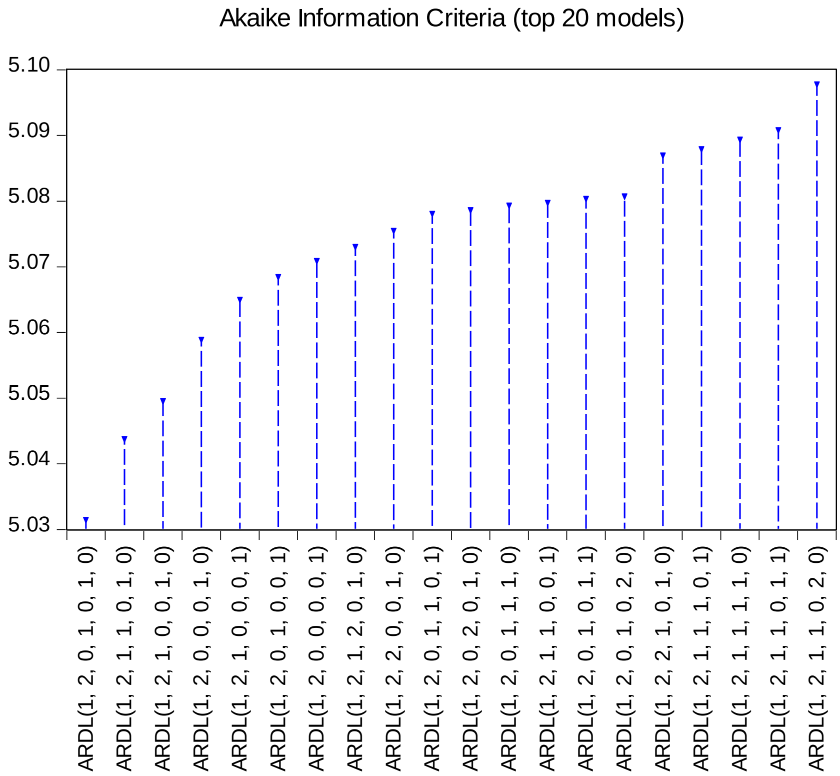


Fig. 1. Number of delays

Source: Authors based on WDI data (2016)

3.2.3 Co-Integration Results: Bound Testing Approach

The results summarised in the table below show that there is a cointegration relationship at the 1% threshold, F-statistic = 6.484024 is well above 4.15.

Table 5. Cointegration table

	F-statistic	Seuil	Confidence interval		Decision
			I_0	I_1	
Cointegration Test	6.484024	10%	2.08	3	There is a cointegration relationship at the 1% threshold.
		5%	2.39	3.38	
		2.5%	2.7	3.73	
		1%	3.06	4.15	

Source: Authors based on WDI data (2016)

3.3 LONG-TERM EFFECT OF CLIMATE CHANGE ON ECONOMIC GROWTH VIA THE AGRICULTURE CANAL

Table 6. Long-term effect of climate change on economic growth via the agriculture canal

Variables	Coef	Prob.
TEMP	-31.83	0.543
TEMP_RCER	53.22	0.709
FBCF	0.395	0.550
IDE	-1.679	0.329
INF	-0.939	0.262
RCER	-56.10	0.696
C	-76.51	0.814

Source: Authors based on WDI data (2016)

The results show that temperature does not affect economic growth through agriculture. This can be explained by the fact that farmers have been able to adapt thanks to ancestral cultivation techniques that are passed on from generation to generation. The country's economic growth potential is also driven by the service sector, which accounts for 38.1% of GDP, and the industrial sector, which accounts for 15.5% of GDP. For example, apart from uranium and several mineral resources that Niger has, it has revolutionised its secondary sector, particularly oil [43].

The same is true for the variables FBCF, IDE, INF and RCER which do not seem to influence economic growth in Niger.

3.4 RESULTS OF ROBUSTNESS TESTS

The results of the diagnostic tests and those of the "CUSUM" and "CUSUMQ" test will form the backbone of this section.

3.4.1 DIAGNOSTIC TEST RESULTS

Still called post-estimation tests, the diagnostic tests were carried out to evaluate the robustness of our model. These tests include: the Lagrange multiplier test for autocorrelation of residuals; the Ramsey functional form test (RESET) for omission of a variable; the Jarque-Bera test for normality of residuals; and the Breusch-Pagan-Godfrey heteroscedasticity test. The results of these tests are summarised in the table below:

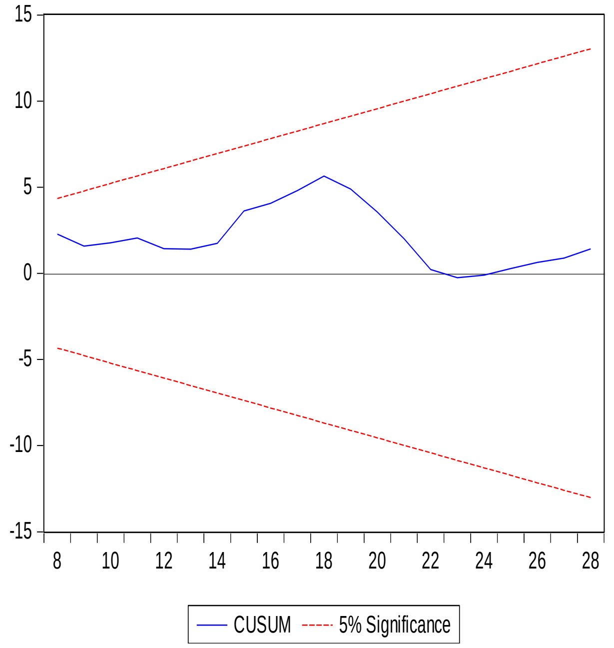
Table 7. Abstract of diagnostic tests

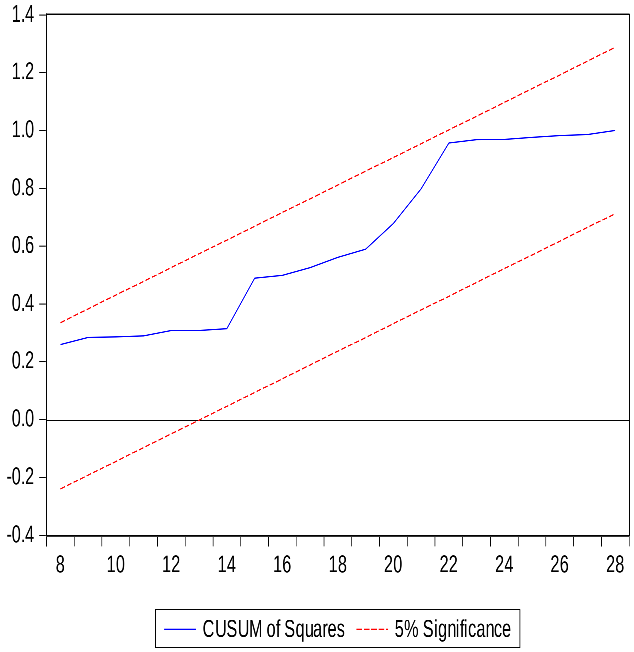
Tests	V. cal	Prob	Décision
Normalité	1,59	0,44	Présence
Autocorrélation	0.29	0.75	Absence
Hétéroscédasticité	1.17	0.36	Absence
d’omission d’une variable	2.28	0.14	Absence

Source: Authors based on WDI data (2016)

3.4.2 Results Of The "CUSUM" And "CUSUMQ" Test

In this study, the results of the CUSUM and CUSUMQ tests are applied to the residuals of the econometric model. The CUSUM and CUSUMQ tests are based on the sum of the residuals. They represent the cumulative sum of the residuals curve, with 5% of the critical lines. The parameters of the model are unstable if the curve lies outside the critical zone, and stable if the curve lies between the two critical lines. The results of our estimations are presented in the graphs below.





Source: *Authors, based on WDI data (2016).*

After analysis, it is also clear that the model parameters are stable, as the curves lie between the two critical lines. We can therefore conclude that our model is robust.

4 Conclusion

This paper aimed to analyse the effect of temperature on economic growth through agriculture in Niger. The method of analysis used was that of the autoregressive lag model (ARDL), developed by [41] which was extended in 2001. The advantage of this method is that it offers us the possibility of having long-term results. As a result, it appears that rising temperatures do not affect long-term economic growth through agriculture in Niger. This can be explained by the adaptation measures taken by farmers. Although our study is based on a period of 37 years, future work can extend this study over a relatively longer period through projection data, and can also use other transmission channels.

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