

Can Agricultural Aid and Remittances Alleviate Macroeconomic Volatility in Response to Climate Change Shocks?

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ABSTRACT : This study investigates the effect of remittance and agricultural aid inflows on GDP growth rate volatility in response to climate change shocks in twenty-eight African countries by using system generalized method of moments from 1996 to 2013 with three years grouped data. The climate change shocks are indicated by four variables; natural disasters, rainfall variability, fluctuation in temperature and the weighted anomaly standardized precipitation (WASP) index. Consequently, natural disasters and temperature variability have a significant effect on GDP volatility, while rainfall variability and WASP index have no adverse consequence on stabilization of the economy. On the other hand, in general, remittances and agricultural aid are helpful to stabilize the economy and especially remittances inflows can play a crucial role as insurance when natural disasters occur.

Keywords : GDP volatility, Economic stabilization, Remittances, Agricultural aid, Natural disaster, Climate change

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아프리카 국가들의 경제성장률 변동성에 기후변화, 송금 및 농업 원조가 미치는 영향 분석[†]

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요약 : 본 연구는 1996년부터 2013년의 경제성장률의 변동성 데이터를 이용하여 아프리카 28개국의 경제적 안정성에 영향을 미치는 요인을 분석한 것이다. 28개 아프리카 국가의 1996년부터 2013년의 연도별 자료를 3년씩 따로 분류하여 총 6개의 시계열 자료를 구축하고 이를 토대로 패널 분석을 수행하였다. 송금 및 농업원조와 경제성장률의 변동성 간의 내생성 문제를 해결하기 위하여 system-GMM (system-Generalized Method of Moments)을 이용하였다. 분석 결과 기후변화를 대표하는 요인 중 자연재해와 온도의 변동성만이 경제 안정성을 악화시키는 요인으로 나타났다. 반면 송금과 농업원조자금은 아프리카 국가들의 경제를 안정시키는 효과를 보이며, 특히 송금의 경우 자연재해 발생에 따른 경제 변동성을 감소시키는 보험의 역할을 하는 것으로 판단된다.

주제어 : 경제 안정성, 경제성장률의 변동성, 기후변화, 자연재해, 농업원조, 송금

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I. Introduction

The Sustainable Development Goals (SDGs) were adopted in 2015 by 191 United Nations countries in order to achieve eight missions including climate change mitigation and adaptation actions. The SDGs threw light on the importance of tackling climate change so as to acquire sustainable development in developing countries. Therefore, this paper aims to evaluate how African nations can achieve sustainable development goals by stabilizing economic growth in response to climate change shocks.

Africa is recognized as the most vulnerable continent to climate change worldwide due to lack of capability to adapt to environmental problems, and insufficient resources and infrastructure (Busby et al., 2012). Especially, Sub-Saharan African countries suffer from low crop production in response to the low level of rainfall, because around 75% of these countries highly depend on rain-fed agriculture for their farming (Brown et al., 2007). Therefore, this study focuses on a particular group of African countries in order to estimate which climate indicators can have the most adverse impact on stabilization of the economy. Thus, this study assesses the relationship between gross domestic product (GDP) growth rate volatility and four given climate variables: natural disasters, fluctuation in precipitation, temperature variability, and the country average weighted anomaly standardized precipitation index (WASP).

While developed countries have stable GDP growth rate for extended periods of time, developing countries historically have fluctuation in GDP growth rate (Lucas, 1988). Therefore, Many studies on developing countries use GDP growth rate volatility as an important variable for evaluating economic stabilization and assessing a potential to be developed since GDP volatility directly leads to welfare cost and indirectly causes underdevelopment (Loayza et al., 2007). Thus, many studies have found a relationship between GDP volatility and external shocks including environmental problems. Raddatz (2007) concluded that external shocks including natural disasters bring about the fluctuation in GDP in low-income developing countries. Hence, this study also assesses the

macroeconomic volatility in response to external shocks caused by environmental problems.

The effectiveness of aid is still controversial for developing countries. Therefore, many recent studies have concentrated on disaggregated aid rather than aggregated aid in order to bring the argument of aid effectiveness to a conclusion (Mavrotas, 2002; Mavrotas, 2005; Cordella and Dell’Ariccia, 2007). Among them, Kaya et al. (2012) used agricultural aid as an independent variable instead of utilizing aggregated aid and found that agricultural aid significantly has a positive relationship with GDP per capita in sixty-six developing countries. Thus, this study would also use agricultural aid as an explanatory variable rather than aggregated aid.

Remittances are another type of significant financial inflow to developing countries, provided with almost more than 300 billion USD annually since 2008 (World Bank, 2011). In this context, many researchers have shed light on a remittances’ risk-pooling function as insurance when external shocks occur, especially in developing countries (Yang and Choi, 2007; Bugamelli and Paternò, 2011; Ebeke and Combes, 2013). Bugamelli and Paternò (2011) concluded that the inflow of remittances had decreased the fluctuation in GDP in sixty developing countries from 1980 to 2003 thanks to its stability, substantial amount, and low level of procyclicality. Also, recently, one of IMF working papers found that remittances have considerable power to alleviate the shock from GDP fluctuation in 27 African countries (Jidoud, 2015). Therefore, this study would evaluate the impact of remittances on economic stabilization in response to climate change shocks in a particular group of African countries.

The aim of this study is to estimate not only the impacts of agricultural aid and remittances to stabilize the economy but also the destabilization effect of climate variables including natural disasters, WASP, and fluctuation in precipitation and temperature on the economy in the given twenty-eight African countries. Through this analysis, this paper could help African nations to plan a national strategy in order to achieve economic stabilization and provide solutions to absorb the shocks caused by environmental problems.

II. Data

Due to lack of data resources for the fifty-four total African countries, we had to restrict the number of countries into the twenty-eight¹⁾ in the dataset. Also, this study examines GDP volatility as a dependent variable following equation (1).

$$V_{i,t} = \frac{\sqrt{(GR_{i,1996} - \overline{GR}_{i,t})^2 + (GR_{i,1997} - \overline{GR}_{i,t})^2 + (GR_{i,1998} - \overline{GR}_{i,t})^2}}{3} \text{ if } t=1. \quad (1)$$

1996 to 2013 is grouped by three-year intervals in each sample to calculate the standard deviation of GDP growth volatility and then create the six time-series (t) in total in each i^{th} country. In equation (1), GR is GDP growth rate in the i^{th} country from 1996 to 2013 and $V_{i,t}$ is the computed standard deviation of GDP growth rate indicating fluctuation in GDP growth rate as the dependent variable.

The major explanatory variables are rainfall variability, temperature variability, WASP-1 and natural disaster, representing climate change shocks for each African country. This study calculates rainfall variability captured through monthly precipitation data from multiple stations.

$$\sigma_{P_{i,t}} = \sqrt{\left(\frac{\sum_{m=1}^{36} P_{i,m} - \overline{P}_{i,t}}{36} \right)^2} \quad (2)$$

In this formula, $P_{i,m}$, $\overline{P}_{i,t}$ and $\sigma_{P_{i,t}}$ are monthly precipitation, mean and standard deviation of monthly precipitation, respectively. The precipitation data is grouped by three-year intervals composed of thirty-six months (m) from 1996 to 2013. Then, this formula finally forms the dataset with six time-series (t), and the given twenty-eight

1) Twenty-eight African countries: Algeria, Benin, Botswana, Cameroon, Egypt, Ethiopia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Madagascar, Malawi, Mali, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, South Africa, Sudan, Swaziland, Tanzania, Togo, Tunisia.

African countries (i).

Temperature variability is also calculated by using data of maximum temperature per month from multiple metrological stations. In equation (3), the data of monthly temperature is standardized by thirty-six months (m) from 1996 to 2013, following the same structure of equation (2).

$$\sigma_{T_{i,t}} = \sqrt{\left(\frac{\sum_{m=1}^{36} T_{i,m} - \overline{T_{i,t}}}{36} \right)^2} \quad (3)$$

In equation (3), $T_{i,m}$, $\overline{T_{i,t}}$ and $\sigma_{T_{i,t}}$ are monthly temperature, mean and standard deviation of monthly temperature data, respectively.

Moreover, the average of the total number of affected people during the given sub-period from natural disasters is used in this model. The reason for selecting the total affected people from natural disasters instead of using the full amount of damage costs is that the damage costs can have an endogeneity problem with the stability of GDP growth rate (Ebeke and Combes, 2013). Also, since remittances or other variables cannot limit and divide their power to stabilize the economy in response to natural disasters, the number of total affected people is chosen regardless of the types of disasters in this study (Ebeke and Combes, 2013). Thus, this paper calculates the mean of total affected people every three years, which are then divided by the entire population at an initial value of each sub-period for determining the share of affected people over the population.

Moreover, this study uses the WASP-1 index for a climate variable, which can show us precipitation abnormalities (Lyon, 2005). The WASP-1 index is not the same as rainfall variability because this index is standardized monthly from the long-term mean of precipitation and provides more detailed information to people on the potentiality of severe drought (WASP-1; below -1) in each country according to equation (4).

$$S_N = \sum_{n=1}^N \left(\frac{Pr_n - \overline{Pr}_n}{\sigma_n} \right) \frac{\overline{Pr}_n}{\overline{Pr}_A} \quad (4)$$

where Pr_n , \overline{Pr}_n and σ_n are monthly precipitation, mean and standard deviation of precipitation, respectively. \overline{Pr}_A indicates the average annual amount of rainfall and N is 12 in order to capture the annual rainfall abnormalities per month. From the WASP index, this study uses an index below -1 (WASP-1) rather than an index above +1 (WASP+1) since WASP +1 cannot directly indicate severe floods due to timescale differences between monthly rainfall and floods (Brown et al., 2011).

The other major independent variables for this study are an agricultural aid and remittances. In order to fit with the dependent variable, these two variables are also measured at the mean value during the given sub-period and then taken by natural logarithms for interpretation.

Also, other factors could be linked to the dependent variable and independent variables. Then, this study uses control variables that have been used in previous studies (Fatas and Mihov, 2003; Bugamelli and Paterno, 2011; Ebeke and Combes, 2013). However, inserting dummy variables of conflict is a point of distinction with other previous studies. The reason why this paper put these variables is that the conflict has substantially affected African economic growth by triggering a large number of fatalities (Stewart et al., 1997). Civil war is defined as more than 1000 deaths from an annual battle, and armed conflict is defined as more than 25 and less than 1000 deaths from a yearly battle (Gleditsch et al., 2002; Themnér and Wallensteen, 2013). Table 1 shows us the all the explanatory variables for this empirical study.

In addition, Table 2 indicates descriptive statistics of the entire variable providing the overall information of the dataset. The number of observations is 168 since we dealt with twenty-eight countries and six non-overlapping sub-periods by dividing 18 years from 1996 to 2013 every three years.

〈Table 1〉 Independent Variables

Variables	Explanation	Data Sources
3.4.1. Climate Variables		
$\overline{TA/PP}$	Total affected people from natural disaster over total population at the beginning sub-period	Natural Disaster: The Emergency Events Database (EM-DAT) Population: World Bank, World Development Indicator
WASP-1	WASP-1 index (drought)	The IRI/LDEO Climate Data Library
$\sigma_{\text{temperature}}$	Temperature variability calculated as the standard deviation of the monthly maximum temperature	
σ_{rainfall}	Rainfall variability computed as the standard deviation of the sum of monthly rainfall	
3.4.2. Agricultural Aid and Remittances		
$\overline{LN.AA}$	Natural logarithms of the agricultural aid	OECD, OECD, iLibrary
$\overline{LN.R}$	Natural logarithms of the remittances	World Bank, World Development Indicator
3.4.3. Control Variables		
σ_{exr}	Exchange volatility measured as the standard deviation of the exchange rate	World Bank, World Development Indicator
chinn1	Chinn- Ito index indicating financial openness	Chinn-Ito Index edited version in 2015 (Chinn and Ito, 2008)
ferretti	Milesi-Ferretti financial openness index	Updated and extended version of Dataset Constructed by Lane and Milesi-Ferretti (2007)
\overline{TO}	Trade openness (sum of export and import over GDP)	Export and import: World Bank, World Development Indicator GDP: IMF, World Economic Outlook Database
\overline{GCR}	Government consumption over GDP	Government consumption: World Bank, World Development Indicator GDP: IMF, World Economic Outlook Database
$\overline{LN.PP}$	Natural logarithms of the total population at the beginning of the given sub-period	World Bank, World Development Indicator
$\overline{LN.PCP}$	Natural logarithms of GDP per capita at the beginning of the given sub-period	IMF, World Economic Outlook Database
\overline{TI}	Total investment over GDP	

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<Table 1> Independent Variables (Continued)

Variables	Explanation	Data Sources
3.4.3. Control Variables		
$\overline{\text{GNS}}$	Gross national savings rate over GDP	World Bank, World Development Indicator
$\overline{\text{AGR}}$	Agricultural shares over GDP	
$\overline{\text{SR}}$	Service shares over GDP	
D.C1	Dummy variable when the number of fatalities is more than 25 and less than 999 called armed conflict (i.e., Armed conflict: 1 and No armed conflict: 0)	UCDP/PRIO, Armed Conflict Dataset v.4-2015
D.C2	Dummy variable when the number of deaths is more than 1000 called civil war (i.e., Civil war: 1 and No civil war: 0)	

<Table 2> Descriptive Statistics

Variable	Obs	Mean	Std.Dev.	Min	Max
African Countries	168	14.500	8.102	1.000	28.000
Time	168	3.500	1.713	1.000	6.000
σGDPR	168	2.065	2.938	0.013	23.450
$\overline{\text{TA/PP}}$	168	0.035	0.074	0.000	0.629
WASP-1	168	3.810	5.817	0.000	32.000
$\sigma\text{temperature}$	168	3.192	1.684	1.108	8.213
$\sigma\text{rainfall}$	168	44.330	24.260	0.000	112.400
$\overline{\text{LN.AA}}$	168	16.370	1.484	10.850	18.940
$\overline{\text{LN.R}}$	168	18.880	2.033	13.480	23.750
$\overline{\text{TA/PP} * \text{LN.R}}$	168	0.641	1.368	0.000	11.270
$\overline{\text{TA/PP} * \text{LN.AA}}$	168	0.578	1.227	0.000	10.170
$(\overline{\text{LN.AA}})^2$	168	270.000	46.700	117.800	358.600
$\overline{\text{D.RM} * \text{TA/PP}}$	168	0.001	0.007	0.000	0.074
σexr	168	34.570	80.820	0.001	621.300
chinn1	168	-0.877	0.886	-1.889	2.390
ferretti	168	-0.532	0.582	-2.693	0.870
$\overline{\text{TO}}$	168	0.702	0.362	0.176	2.824

〈Table 2〉 Descriptive Statistics (Continued)

Variable	Obs	Mean	Std.Dev.	Min	Max
$\overline{\text{GCR}}$	168	0.151	0.070	0.027	0.521
$\overline{\text{LN.PP}}$	168	15.950	1.228	13.310	18.500
$\overline{\text{LN.PCP}}$	168	6.661	0.986	4.760	8.998
$\overline{\text{TI}}$	168	21.770	8.452	4.747	59.260
$\overline{\text{GNS}}$	168	17.380	10.470	-6.724	54.470
$\overline{\text{AGR}}$	168	26.590	14.340	2.281	58.200
$\overline{\text{SR}}$	168	47.260	9.709	13.860	67.740
D.C1	168	0.190	0.394	0.000	1.000
D.C2	168	0.083	0.277	0.000	1.000

III. Model Specification and Estimation Method

1. Model Specification

This study begins with the estimation of the impact of rainfall variability, temperature variability, WASP-1, and natural disasters on economic growth rate volatility from the following equation:

$$V_{i,t} = \alpha V_{i,t-1} + \beta X_{i,t} + \gamma_1 PR_{i,t} + \tau_1 TP_{i,t} + \delta_1 D_{i,t} + \varphi_1 WD_{i,t} + c_i + u_t + \epsilon_{i,t}$$

for $t=1, \dots, 6$. (5)

where $V_{i,t}$ represents the GDP rate volatility in country i and time t (three non-overlapping years during the given period from 1996 to 2013), $V_{i,t-1}$ indicates that the lagged dependent variable, $X_{i,t}$ is a set of control variables (Table 1) showing us countries' characteristics, $PR_{i,t}$ is the standard deviation of monthly precipitation, $TP_{i,t}$ is the standard deviation of the maximum monthly temperature, $D_{i,t}$ represents the mean of the total affected people from natural disasters over the total population at the beginning of

the given sub-periods, $WD_{i,t}$ is the sum of the number of WASP below -1 over sub-periods, c_i is the country-fixed effect, u_t is the period dummies and $\epsilon_{i,t}$ represents the error term. In the equation, this study assumes that $\gamma_1 > 0$, $\tau_1 > 0$, $\delta_1 > 0$, and $\varphi_1 > 0$ as climate variables might have a negative impact on economic stabilization in the twenty-eight African countries.

The second equation estimates the effect of other variables such as agricultural ODA and remittances on GDP stability by subtracting disasters, WASP-1 index, and fluctuation in precipitation and temperature variables. The following formula can help us to find the answer on whether agricultural aid and remittances can or cannot stabilize the economy by themselves in the given countries.

$$V_{i,t} = \alpha V_{i,t-1} + \beta X_{i,t} + \theta_1 R_{i,t} + \omega_1 AA_{i,t} + c_i + u_t + \epsilon_{i,t} \quad (6)$$

where $R_{i,t}$ and $AA_{i,t}$ are the remittances and the agricultural ODA variable, respectively. These two variables use natural logarithms. Here, the coefficients of remittance and agricultural aid inflows might be negative, $\theta_1 < 0$ and $\omega_1 < 0$ because of their roles to stabilize the economy.

The third equation analyzes the relationship between GDP growth variability and all variables including climate variables, remittances, and agricultural aid.

$$V_{i,t} = \alpha V_{i,t-1} + \beta X_{i,t} + \pi_2 CR_{i,t} + \omega_2 AA_{i,t} + \theta_2 R_{i,t} + c_i + u_t + \epsilon_{i,t} \quad (7)$$

In equation (7), the expectation is $\omega_2 < 0$ and $\theta_2 < 0$ in contrast with $\pi_2 > 0$. We assumed that agricultural aid and remittances can lower GDP volatility while climate variables ($CR_{i,t}$) adversely affect macroeconomic stabilization. In addition, we expected that the coefficients for climate change variables might be $|\pi_2| > |\pi_1|$ where π_1 is the significant coefficient values of climate variables from the equation (5) including natural disasters, WASP -1, fluctuation in precipitation and temperature. Climate variables only

capture the direct impact on GDP rate volatility in equation (7) and do not seize the indirect impact of increasing remittances inflows in response to environmental shocks by putting these two factors in the equation at the same time. This indirect effect occurs since citizens make an effort to adjust their own economy by raising the amount of remittances as insurance after the outbreak of climate change shocks (Mohapatra et al., 2009; David, 2010; Ebeke and Combes, 2013). However, it is not certain that the coefficients of remittances are $|\theta_2| < |\theta_1|$ due to other variables such as trade openness and governmental spending. Ebeke and Combes (2013) found that trade openness has a significant and positive effect after involving climate variables and remittance together.

$$V_{i,t} = \alpha V_{i,t-1} + \beta X_{i,t} + \pi_3 CR_{i,t} + \omega_3 AA_{i,t} + \theta_3 R_{i,t} + \theta_4 CR_{i,t} * R_{i,t} + c_i + u_t + \varepsilon_{i,t} \quad (8)$$

$$V_{i,t} = \alpha V_{i,t-1} + \beta X_{i,t} + \pi_4 CR_{i,t} + \omega_4 AA_{i,t} + \theta_5 R_{i,t} + \omega_5 CR_{i,t} * AA_{i,t} + c_i + u_t + \varepsilon_{i,t} \quad (9)$$

Equations (8) and (9) are objectives to examine the association between climate variables and remittances or agricultural aid when the climate variables and the main independent variables have a significant effect through equations (5), (6) and (7). The major assumption is that $\pi_3 > 0$, $\theta_4 < 0$, $\pi_4 > 0$ and $\omega_5 < 0$.

$$\frac{\partial V_{i,t}}{\partial CR_{i,t}} = \pi_3 + \theta_4 R_{i,t} = 0 \rightarrow R^* = -\frac{\pi_3}{\theta_4} \quad (8-1)$$

$$\frac{\partial V_{i,t}}{\partial CR_{i,t}} = \pi_4 + \omega_5 AA_{i,t} = 0 \rightarrow AA^* = -\frac{\pi_4}{\omega_5} \quad (9-1)$$

If the result follows this presumption, we can calculate the minimum amount of remittances and agricultural aid, which can dampen the destabilization effect of climate change.

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$$V_{i,t} = \alpha V_{i,t-1} + \beta X_{i,t} + \pi_5 CR_{i,t} + \omega_6 AA_{i,t} + \theta_6 R_{i,t} + \omega_7 (AA_{i,t})^2 + c_i + u_t + \varepsilon_{i,t} \quad (10)$$

However, agricultural aid cannot immediately flow into countries in response to climate change shocks, unlike remittances, since agricultural aid highly depends on the intentions of donors. Therefore, if the interaction variable in equation (9) does not have the significant effect, then equation (10) would be used to find the exact trend for the impact of aid to agricultural development on GDP fluctuation.

$$\frac{\partial V_{i,t}}{\partial AA_{i,t}} = \omega_6 + \omega_7 AA_{i,t} = 0 \rightarrow AA^* = -\frac{\omega_6}{\omega_7} \quad (10-1)$$

Also, if the coefficients of agricultural aid and the given quadric form are $\omega_6 < 0$, and $\omega_7 > 0$, we can calculate equation (10-1) that helps us to know when farm aid loses its power to stabilize the economy.

All of the equations above from (5) to (9), except for (10), assume the entire variable have a linear association with GDP volatility. Fundamentally, following previous studies (Bugamelli and Paternò, 2011; Ebeke and Combes, 2013), the linear equation was constructed for this model. Especially, for fluctuation in rainfall and temperature, a quadric form was not selected in previous research papers (Barrios et al., 2010; Dell et al., 2012). Moreover, according to Kaya et al. (2012), this article uses lagged agricultural aid data as one of the instrumental variables through system-GMM estimator rather than using it as an independent variable in equation (7), (8), (9), and (10).

Many studies recognize that remittances have an endogeneity problem with a fluctuation in GDP growth rate (Bugamelli and Paternò, 2011; Ebeke and Combes, 2013). However, in regard to agricultural ODA, there is a little study to deal with the relationship with output volatility. Destabilization of the economy negatively affects economic growth and subsequently a low level of economic growth can cause fluctuation in GDP (Aizenman and Pinto, 2005). Thus, Agricultural aid could also have

an endogeneity problem with macroeconomic fluctuation because agricultural aid is endogenous with economic growth (Kaya et al., 2012). Hence, this study utilizes the estimator of the system-generalized method of moments (system-GMM) with instruments (i.e. lagged difference and levels of explanatory variables) (Bludell and Bond, 1998), instead of Ordinary Least Square (OLS).

IV. Empirical Results

1. Analysis of Findings from system-GMM

Table 3 shows the results for all of the above equations. The system-GMM estimator is one of the dynamic panel models with a presumption of a lagged dependent variable's significant effect on the dependent variable. Table 3 shows that for all types of equations, the coefficients of the lagged dependent variable ($\sigma_{\text{GDPR}(t-1)}$) significantly have a positive impact on output growth volatility.

〈Table 3〉 Results of Equations (5), (6), (7), (8), (9), and (10)

Parameters	(5)	(6)	(7)	(8)	(9)	(10)
$\sigma_{\text{GDPR}(t-1)}$	0.232**	0.245**	0.222**	0.223**	0.225**	0.230**
	(0.092)	(0.120)	(0.100)	(0.105)	(0.096)	(0.106)
$\overline{\text{TA/PP}}$	5.083**		5.743**	56.895**	-59.395	6.065***
	(2.402)		(2.298)	(25.433)	(57.517)	(2.335)
WASP-1	-0.024		-0.023	-0.010	-0.024	-0.019
	(0.037)		(0.034)	(0.036)	(0.033)	(0.036)
$\sigma_{\text{temperature}}$	0.914*		0.791	0.848*	0.767	0.781*
	(0.511)		(0.510)	(0.498)	(0.486)	(0.472)
σ_{rainfall}	0.015		0.013	0.016	0.012	0.016
	(0.031)		(0.030)	(0.029)	(0.029)	(0.029)
$\overline{\text{LN.AA}}$		-0.540**	-0.564**	-0.551**	-0.619**	-4.398*
		(0.262)	(0.274)	(0.263)	(0.252)	(2.354)

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<Table 3> Results of Equations (5), (6), (7), (8), (9), and (10) (Continued)

Parameters	(5)	(6)	(7)	(8)	(9)	(10)
$\overline{\text{LN.R}}$		-0.838*	-0.839**	-0.701*	-0.956***	-1.032***
		(0.470)	(0.331)	(0.359)	(0.322)	(0.317)
$\overline{\text{TA/PP} * \text{LN.R}}$				-2.780**		
				(1.351)		
$\overline{\text{TA/PP} * \text{LN.AA}}$					3.983	
					(3.525)	
$(\overline{\text{LN.AA}})^2$						0.127*
						(0.076)
σ_{exr}	0.003	-0.001	0.001	0.001	0.000	0.000
	(0.006)	(0.005)	(0.006)	(0.006)	(0.006)	(0.005)
chinn1	-0.191	-0.275	-0.241	-0.296	-0.300	-0.072
	(0.766)	(0.456)	(0.565)	(0.560)	(0.584)	(0.591)
ferretti	0.476	0.377	0.641	0.647	0.576	0.757
	(1.285)	(0.933)	(1.025)	(1.035)	(1.055)	(0.946)
$\overline{\text{TO}}$	2.168	1.656	2.430*	2.759**	1.891	2.129
	(1.406)	(1.264)	(1.317)	(1.282)	(1.656)	(1.487)
$\overline{\text{GCR}}$	-12.216*	-13.249**	-15.090**	-16.243**	-12.280	-14.013*
	(7.320)	(6.621)	(7.334)	(7.014)	(7.493)	(7.850)
$\overline{\text{LN.PP}}$	-1.378	-0.731	-2.799	-2.990	-4.220	-3.410
	(4.990)	(4.616)	(4.797)	(4.685)	(5.238)	(5.050)
$\overline{\text{LN.PCP}}$	-0.337	0.608	0.122	0.174	-0.094	-0.157
	(2.172)	(2.063)	(1.892)	(1.895)	(1.960)	(1.919)
$\overline{\text{TI}}$	0.046	0.056	0.032	0.025	0.033	0.048
	(0.041)	(0.045)	(0.039)	(0.039)	(0.040)	(0.040)
$\overline{\text{GNS}}$	-0.121*	-0.153*	-0.123*	-0.116*	-0.106	-0.125*
	(0.070)	(0.083)	(0.068)	(0.069)	(0.072)	(0.071)
$\overline{\text{AGR}}$	-0.144	-0.094	-0.137	-0.130	-0.130	-0.158
	(0.091)	(0.088)	(0.099)	(0.101)	(0.097)	(0.102)
$\overline{\text{SR}}$	-0.129	-0.132	-0.101	-0.085	-0.098	-0.130
	(0.109)	(0.126)	(0.103)	(0.106)	(0.101)	(0.108)
D.C1	0.625	0.744	0.388	0.536	0.266	0.294
	(0.555)	(0.570)	(0.477)	(0.474)	(0.484)	(0.491)

〈Table 3〉 Results of Equations (5), (6), (7), (8), (9), and (10) (Continued)

Parameters	(5)	(6)	(7)	(8)	(9)	(10)
D.C2	2.310	1.926	1.827	1.981	2.008	2.044
	(1.773)	(2.321)	(2.002)	(2.021)	(2.018)	(2.039)
_cons	32.410	44.897	78.957	77.507	106.529	126.135
	(81.633)	(81.555)	(81.030)	(79.893)	(91.812)	(89.273)
Number of observations	140	140	140	140	140	140
Number of countries	28	28	28	28	28	28
First-order serial correlation P-value	0.0183	0.0326	0.0260	0.0252	0.0285	0.0340
Second-order serial correlation p-value	0.1537	0.3043	0.2960	0.2914	0.3629	0.3073
Sargan: over-identification test p-value	0.1826	0.8037	0.8514	0.8490	0.8722	0.8887
Number of instruments	36	60	64	65	65	65

Note: these results are calculated by using one-step system-GMM with small sample robust correction and including time effects. The dummy variables of time1, time6 and Guinea-Bissau were automatically omitted due to multicollinearity. According to Sargan test, the null hypothesis was not rejected in all of the results, which means that all the models are satisfied with moment conditions and there is no over-identification problem. Moreover, in all the results from the test for zero autocorrelation in the first-differenced error, the null-hypothesis of first-order correlation was rejected, and it failed to reject that of the second-order serial correlation. These indicate that the error term is uncorrelated with the time series.

Numbers in parentheses are standard errors. ***, **, * designate significance at 1%, 5% and 10%, respectively.

In particular, each equation has to be considered in order to show the detailed results. First, in equation (5), we assumed that $\gamma_1 > 0$, $\tau_1 > 0$, $\delta_1 > 0$ and $\varphi_1 > 0$ because climate change shocks could raise the fluctuation in GDP growth rate. However, the null-hypothesis (H_0) for γ_1 and φ_1 was not rejected in Table 3. Only natural disaster and

temperature variability have a significant effect by satisfying the earlier assumption. When $\frac{\overline{TA}}{\overline{PP}}$ (total affected people from natural disasters) increase 1% point, it raises GDP growth rate volatility by 5.083.

In addition, without the climate variables in equation (6) and at a research design level, we expected that remittances and agricultural aid would be $\theta_1 < 0$ and $\omega_1 < 0$. In Table 3, we can see that this presumption is true. When remittances increase by 1%, the remittances could help the reduction of GDP volatility by 0.838. Also, when the agricultural aid increases by 1%, economic volatility is reduced by 0.540.

The results also show in equation (7) that when the proportion of total affected people from natural disasters over the total population increases by 1% point, the fluctuation in GDP can increase by 5.743. Moreover, aid to agricultural development and remittances in this equation with climate variables still have a decreasing effect on macroeconomic volatility. The absolute value of the coefficient of natural disasters also increases from 5.083 to 5.743 ($|\pi_2| > |\pi_1|$) since this can only seize the direct effect of natural disasters without catching the indirect effect of raising the remittance inflows. However, in equation (7), the absolute remittances' value does not reduce but slightly rises from 0.838 to 0.839 ($|\theta_2| > |\theta_1|$). Nevertheless, this does not mean that remittances cannot play a role as insurance for developing countries in response to climate change shocks since in equation (8), the interaction variable between natural disasters and remittances significantly has a negative impact on output growth rate fluctuation. Moreover, when we insert natural disaster and remittance variables together in equation (7), the coefficient of trade openness becomes a significant value, leading to an increase in macroeconomic volatility.

In equation (8), the objectives are to estimate an interaction term ($\overline{TA/PP * LN.R}$) in order to seize the relationship between natural disasters and remittances and to calculate the minimum required level of remittances with a view for reducing the economic shocks when natural disasters occur. The previous assumption in equation (8) is correct

following these results: $\pi_3 > 0$, and $\theta_4 < 0$. After inserting the interaction terms, the absolute coefficients of remittances decrease from 0.839 to 0.701 $|\theta_2| > |\theta_3|$ since the value of θ_3 cannot entirely capture the effect from the relationship with natural disasters. Moreover, π_3 and θ_4 values have a significant effect on the fluctuation in the output growth rate. Thus, it is available to measure the minimum level of remittances required to dampen the risk of natural disaster causing economic instability. Following equation (8-1), the minimum amount of log of remittances is around 20.466 ($R^* = -\frac{\pi_3}{\theta_4} = -\frac{56.895}{2.780} \approx 20.466$). This means that the twenty-eight African countries need at least around 0.71 billion USD of remittance inflows on average.

In equation (9), unlike equation (8), π_4 and ω_5 do not have a significant effect. This means that agricultural aid can reduce macroeconomic volatility in itself. However, the amount of agricultural aid cannot automatically increase in response to natural disasters. Thus, equation (10) involving the quadratic form of agricultural aid was implemented to know the trend of agricultural aid toward GDP growth rate volatility and to calculate the certain point when the agricultural aid has a reversed effect in the given countries. Table 3 shows us that $\omega_6 < 0$ and $\omega_7 > 0$. It indicates that agricultural aid can reduce GDP growth rate volatility ($\omega_6 < 0$). However, a certain level of agricultural aid could lead to GDP destabilization ($\omega_7 > 0$) due to a huge amount of inflows of capital from aid to the country. Additionally, we can measure the amount of agricultural aid that creates GDP destabilization by using the $AA^* = -\frac{\omega_6}{\omega_7}$ formula in equation (10-1). AA^* is approximately 34.630 and suggests that up to the amount of 2.718^{34.630} USD (≈ 1 quadrillion) agricultural aid can alleviate output growth rate volatility. In other words, surplus inflows of agricultural aid can also create economic instability. However, the amount of agricultural aid inflows over one quadrillion USD currently does not exist in these twenty-eight African countries. Moreover, this amount of aid for agricultural development to these particular African countries is dramatically huge in reality. Thus, it is evidenced

that agricultural aid reduces the risk of destabilization of GDP growth rate in general in the given countries.

From all equations, natural disasters are the most serious environmental shocks rather than changes in the weathers' pattern and the precipitation abnormality (WASP-1) in the twenty-eight surveyed African countries. It is likely that this result came up because the natural disaster variable was captured from the total affected people and this variable directly stands for natural disasters' effect on people's life.

2. Marginal Effect of Natural Disasters

In the previous section, we calculated the minimum value of remittances to be more than $R^* = 20.466$. When the remittances inflows are around 0.71 billion USD for each country, it can help to reduce the natural disasters' marginal effect of destabilizing GDP growth rate. Thus, in Table 4, this study involves the interaction variable between dummy variables of remittances ($\overline{LN.R} \geq 20.466$: 1, $\overline{LN.R} < 20.466$: 0) and natural disaster ($\overline{TA/PP}$) in equation (7). Since the values of $\overline{TA/PP}$ and $D.RM^* \overline{TA/PP}$ have a significant effect on the dependent variable, we can measure the marginal effect of natural disasters by combining the coefficient of $\overline{TA/PP}$ and $D.RM^* \overline{TA/PP}$ ($6.223 + -21.316 = -15.093$) according to the formula (Ebeke and Combes, 2013) based on the results in Table 4.

〈Table 4〉 Results of Post-estimation of Natural Disaster
($D.rm = 1$ if $\overline{LN.R} \geq 20.466$)

Parameters		Parameters	
$\sigma_{GDPR(t-1)}$	0.202** (0.101)	$\overline{LN.PP}$	-2.939 (4.838)
$\overline{TA/PP}$	6.223*** (2.350)	$\overline{LN.PCP}$	0.002 (1.861)
WASP-1	-0.018 (0.032)	\overline{TI}	0.016 (0.037)
$\sigma_{temperature}$	0.864* (0.513)	\overline{GNS}	-0.118* (0.066)

(Table 4) Results of Post-estimation of Natural Disaster (Continued)

(D.rm = 1 if $\overline{\text{LN.R}} \geq 20.466$)

Parameters		Parameters	
σ_{rainfall}	0.021 (0.031)	$\overline{\text{AGR}}$	-0.156 (0.105)
$\overline{\text{LN.AA}}$	-0.603** (0.253)	$\overline{\text{SR}}$	-0.098 (0.103)
$\overline{\text{LN.R}}$	-0.635** (0.313)	D.C1	0.477 (0.455)
$\overline{\text{D.RM*TA/PP}}$	-21.316*** (7.558)	D.C2	1.684 (1.968)
σ_{ex}	0.001 (0.006)	Intercept	79.017 (81.163)
chinn1	-0.303 (0.560)	Number of observations	140
ferretti	0.424 (1.057)	Number of countries	28
		First-order serial correlation P-value	0.0232
		Second-order serial correlation p-value	0.2719
$\overline{\text{TO}}$	2.693** (1.326)	Sargan: over-identification test p-value	0.8310
$\overline{\text{GCR}}$	-16.857** (7.139)	Number of instruments	65

Note: The dummy variables of time1, time6 and Guinea-Bissau were automatically omitted due to multicollinearity. Through the Sargan test, the null hypothesis was not rejected in all the results, which means that all the models are satisfied with moment conditions and there is no over-identification problem. Moreover, in all the results from the test for zero autocorrelation in first-differenced error, the null-hypothesis of first-order correlation was rejected, and it failed to reject that of second-order serial correlation. These indicate that the error term is uncorrelated with time series.

Numbers in parentheses are standard errors. ***, **, * designate significance at 1%, 5% and 10%, respectively.

V. Conclusion

This paper analyzes climate factors that most severely affect macroeconomic volatility, and if remittances and agricultural aid are available or not to stabilize output

growth rate in the selected twenty-eight African countries by using the system-GMM estimator. From the study results, natural disasters have a significant effect on economic destabilization rather than other climate variables during the given sub-period in these particular African countries.

Moreover, all of the results show that inflows of remittances and agricultural aid can induce economic growth rate stability. Importantly, remittances have a marginal effect on reducing the climate change shocks to output growth volatility when they are more than around 0.71 billion USD. It can provide African policy makers with the basic guidelines highlighting that they should take this amount of remittance inflows into account, especially if they suffer from natural disasters. Thus, these particular African countries should assure their population to be easily and freely able to transfer cash from other foreign countries. Moreover, low transaction cost could also be considered for their national policy in order to encourage migrants to send money to their family.

Presently, one of the most substantial factors to stabilize these particular countries' economy is to improve the amount of agricultural aid. Unlike remittances, aid for agricultural development is not related to natural disasters because agricultural aid usually reflects the donor's objectives in reality. However, this result contributes to an aid plan for donor countries suggesting that a considerable amount of agricultural aid is needed in these particular African countries as long as agricultural aid has the power to stabilize the economy. Also, domestic policy makers in these specific countries should dwell on agricultural aid in order to manage, and moderate output growth rate instability since destabilization of the economy could lead to underdevelopment in the given countries.

Nevertheless, this study has limitations. First, this study provides statistical analysis at a superficial level due to the absence of data for estimating the extended period. On the other hand, these findings would be valuable for developing countries as they currently cope with natural disasters and suffer from economic instability, which has a potential to bring about underdevelopment. Second, the relationships between climate indicators, economic stabilization, and other variables require more precise exploration in the future

with larger countries' dataset than the current research regardless of regions. It can better assist more developing countries to deal with the threat from climate factors and to reduce the environmental shocks to economic instability.

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