

Houngbédji, Honoré Sèwanoudé; Bassongui, Nassibou

Article

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Research in Globalization

Provided in Cooperation with:

Elsevier

Suggested Citation: Houngbédji, Honoré Sèwanoudé; Bassongui, Nassibou (2023) : Threshold effect of financial stability on monetary policy in West Africa, Research in Globalization, ISSN 2590-051X, Elsevier, Amsterdam, Vol. 6, pp. 1-7,
<https://doi.org/10.1016/j.resglo.2023.100122>

This Version is available at:

<https://hdl.handle.net/10419/331049>

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Threshold effect of financial stability on monetary policy in West Africa

Honoré S. Hounbédji, Nassibou Bassongui*

Faculty of Economics and Management, University of Abomey-Calavi, Benin

ARTICLE INFO

JEL Code:
E52-E58-C32

Keywords:
Financial stability
Monetary Policy
Threshold Effect
Smooth Transition
TAR
STAR

ABSTRACT

This article aims to highlight the nonlinearity of the reaction function of the Central Bank of West African States (BCEAO) through financial stability. Using the smooth threshold autoregressive (STAR) model on aggregate data for the period 1970–2020, the study reveals that the dynamics of the BCEAO monetary policy are conditioned on financial stability, especially when using the money supply ratio as an indicator of financial stability. Thus, the BCEAO reacts to a financial instability risk when the volatility of the latter exceeds a threshold. In particular, the BCEAO adopts a restrictive monetary policy by raising its interest rate when the deviation of the financial stability index is greater than the estimated threshold. These results indicate that the BCEAO should take into account the cyclical component of the money supply ratio in conducting monetary policy. This strategy could prevent financial instability risks.

1. Introduction

Recent literature has highlighted the role of central banks in financial stability beyond their conventional role of price stability (Gourinchas and Obstfeld, 2012; Laseen & Pescator, 2020). The 2007 financial crisis and the recent COVID-19 pandemic provided further proof of the need for this new paradigm that monetary authorities must adopt. Thus, to tackle the negative impact of COVID-19 on the banking system in the WAEMU region, the Central Bank of West African States (BCEAO) has for the first time increased the resources available to banks. For the second time, the BCEAO set up an interest rate subsidy fund, which is a maturity deferral mechanism for companies that encounter difficulties in repaying the loans granted to them (BCEAO, 2020). Although these interventions go beyond the conventional goal assigned to central banks, they are not without consequences for the preservation of the stability of the financial system.

In theory, there is debate about whether financial stability should be assigned as another objective of central banks. In the first group of authors, namely the separate approach, argues that integrating financial stability into the reaction function of central banks would be counterproductive to the extent that strategy would further strengthen the divergences between economies (Svensson, 2012; Gali, 2014, Laseen & Pescator, 2020). In contrast, the second group, the “integrated approach”, think that monetary policy can support macroprudential policy by adjusting the policy rate according to financial conditions

(Mishkin, 2011; Woodford, 2012). Thus, central banks must take financial stability into account in their monetary policy by combining the regulatory aspect and monetary stability through asset prices in the Taylor rule (Allegret, 2017; Boyarchenko, Favara, & Schularick, 2022). Hence, financial stability becomes the second objective of monetary policy. In this regard, central banks can adopt a monetary policy of the type “leaning against the wind”. This consists of gradually shifting, in periods of expansion, to a more restrictive monetary policy to avoid excess indebtedness and asset price bubbles, both leading to a financial crisis and a recession. Hence, the literature shows that price stability is a sufficient condition for financial stability (Borio, 2014). Such an idea has been widely supported by the financial crisis, which showed a very close link between price stability and financial stability (Schularick and Taylor, 2012). However, this policy of “Leaning against the Wind” has often been rejected by central banks (Artus, 2020). For this author, the monetary authorities believe that high-interest rates would force the increase in assets or debt prices and that this would weaken the economy.

Although the theoretical arguments in favour of financial stability are relevant, the empirical verification of these two approaches yields two main results. The first group of authors finds the existence of a linear relationship between monetary policy and financial stability (Aikman, Haldane, & Nelson, 2015; and Nair & Anand, 2020; Chen & Phelan, 2022). Brunnermeier (2016) argued that there is no relationship between price stability and financial stability. Thus Laseen and Pescator

Abbreviations: TAR, Threshold Auto Regressive; STAR, SmoothThreshold Auto Regressive.

* Corresponding author.

E-mail address: nassibou.bassongui@cesag.edu.sn (N. Bassongui).

<https://doi.org/10.1016/j.resglo.2023.100122>

Received 26 October 2022; Received in revised form 19 January 2023; Accepted 20 February 2023

Available online 23 February 2023

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(2020) advised against the Canadian central bank using monetary policy to ensure financial stability; to the extent that the relationship between the ratio of credit to the economy and the likelihood of a financial crisis occurring is uncertain.

Another strand of the literature supports for a nonlinear relationship in conducting monetary policy (Floro and van Roye, 2017; Dibooglu, Seyfettin, Durmus Cagri, & Cevik, 2020; Hounghédji & Bassongui, 2022). In the WAEMU region, three major contributions should be noted. First, Trinnou (2016) shows that monetary policy is only effective when bank credit risk is below the threshold of 18.8%. Gbenou (2017) indicates that in a regime of financial stress, restrictive monetary policy harms economic growth, while the opposite effect is observed in a regime of low financial stress. Lastly, Hounghédji and Bassongui (2022) indicated that the BCEAO reacts to the risk of financial instability by increasing the short-term interest rate when the financial stability index reaches a given threshold.

Overall, the results of these studies on the relationship between monetary policy and financial stability are mixed. Likewise, the analysis of stylized facts relating to the dynamics of BCEAO monetary policy and financial stability indicators yields mixed results. Indeed, the BCEAO interest rate fell from 4.7% over the period 2000–2008 to 3.75% over the period 2009–2019. Over these respective periods, the financial stability measured by the average z-score index of banks fell from 0.16 to 0.11 (BCEAO, 2020) [1]. In addition, the ratio of non-performing loans increased from 17.1% to 11.8% (BCEAO, 2020). These statistics reveal that an expansionary monetary policy is accompanied by a weak resilience of the financial sector (reduction in z-score). Moreover, an expansionary monetary policy leads to better financial stability and banking through the decline in the level of nonperforming loans. This ambiguous relationship between financial stability and monetary policy could result from nonlinearity in the financial stability and monetary policy nexus. In this regard, this paper aims to assess the impact of financial stability on the monetary policy of the BCEAO by adopting a suitable methodological framework that takes nonlinearity into account.

This paper contributes to filling the literature gap on the response of monetary policy toward financial stability in African countries, in particular the monetary policy of the BCEAO. Second, this study differs from existing studies by using an alternative indicator of financial stability. We use the variance of the cyclical component of the financial development indicator captured by three ratios (money supply/GDP, credit to the economy/GDP, liquid assets/total assets). This measure has the advantage of highlighting its dynamics and best captures the degree of volatility of these indicators. Third, we take into account the specificity of the study area concerning the fixed exchange rate regime in the specification of the BCEAO's reaction function. The choice of a STAR (Smooth Threshold Autoregression) model instead of an STR (Smooth Transition Regression) is justified by our theoretical framework. Indeed, Taylor's rule introduces the lag in the key central bank interest rate as an explanatory variable in the monetary policy reaction function. From a managerial point of view, this paper provides empirical evidence in favour of taking into consideration financial stability in the conduct of BCEAO's monetary policy. This will reduce the vulnerability of the zone to the risks of financial instability. The rest of the paper is as follows: section 2 presents a synthesis of the empirical literature, and section 3 exposes the methodology and data used. Section 3 presents and discusses the main findings. Lastly, section 4 concludes.

2. Synthesis of the empirical literature

Empirically, the pioneering literature on the integration of the Taylor rule augmented by financial stability goes back to the work of Borio and Lowe (2004) and McCulley and Toloui (2008). These works consider respectively the credit spread and the change in the exchange rate to capture financial stability in the central bank's reaction function. This literature on the relationship between monetary policy and financial stability leads to two main results based on DSGE and Bayesian VAR

modeling via the Taylor rule.

The first group of studies found a linear relationship. Thus, Nair and Anand (2020) study the relationship between monetary policy and financial stability in India. Using the Generalized Method of Moments (GMM), they showed that the Indian central bank combats financial instability effectively when it targets asset prices in setting monetary policy. More recently, Chen and Phelan (2022) adopted a macro-econometric model and find that monetary policy promotes financial stability and improves households' welfare. Furthermore, using a time-varying vector-autoregressive model (TVP-VAR), Hao et al. (2022) indicated that monetary policy can promote financial stability in China in the short run. These findings confirmed those from Merrouche and Nier (2017) under a DSGE framework.

The second group of studies argues that the relationship between monetary policy and financial stability depends on the inflation-targeting regime. The study of Cairo and Sim (2020) shed new light on the issue and suggested that the central bank can improve both price stability and financial stability when it adopts an aggressive inflation-targeting regime. More importantly, using the augmented Taylor rule for asset prices, Nair and Anand (2020) suggested that asset price targeting can be one of the effective ways to contain financial instabilities and the resulting economic crises in India. Ajisafe (2021) also found that monetary policy has a positive influence on financial stability through the exchange rate channel in Nigeria.

In contrast to previous studies, other studies postulated that monetary policy harms financial stability. Among these studies, Blot et al. (2015) rejected the hypothesis that price stability serves financial stability. Instead, they found that using the policy interest rate for financial stability purposes depends on the country. Raising the interest rate to contain credit expansion is successful in the case of the US. However, this is not the case for the European Union.

Another strand of the literature indicates that monetary policy does not affect financial stability. In this line, Laseen and Pescator (2020) showed that it is not appropriate for the Canadian central bank to use monetary policy to ensure financial stability via an equilibrium of household debt and house price growth. The simulations show that the monetary policy shock affects the probability of a crisis (financial instability) with a long lag. Similarly, the relationship between credit to the economy and the probability of a financial crisis is uncertain. The general point raised by the above literature is the existence of a linear relationship between monetary policy and financial stability. This framework is often justified in times of stability. However, in the context of recurrent crises that affect economies, the underlying relationships may have changed (Mishkin, 2009). The identification of a non-linear relationship in the conduct of monetary policy becomes a major issue.

The literature on monetary policy is abundant and has demonstrated a non-linear relationship between monetary policy and financial stability. In this respect, Dibooglu et al. (2020) adopted a Markov regime-switching model and showed the existence of a non-linear relationship in the reaction function of the FED's monetary policy. Notably, they indicated that the effect of financial stability on the FED's monetary policy is not significant when financial stability is taken into consideration in the reaction function. However, when financial stability is included, the study found that the probability of moving from a low (or calm) to a high (or distressed) regime becomes greater than 50% when the financial index exceeds a threshold of 1.25. The result shows that the FED seems to take into account the objective of financial stability in the transition from one regime to the other. Most recently, Hounghédji and Bassongui (2022) examine the role of financial stability in the dynamics of monetary policy at the BCEAO. The study used a Markov regime-switching model to indicate that BCEAO's monetary policy is characterised by two regimes depending on the financial stability index. The study showed that the BCEAO reacts to the risk of financial instability by increasing its short-term interest rate when the financial stability index reaches 49 (credit to the economy/GDP) and 31 (money supply/GDP).

In sum, empirical tests of the link between monetary policy and

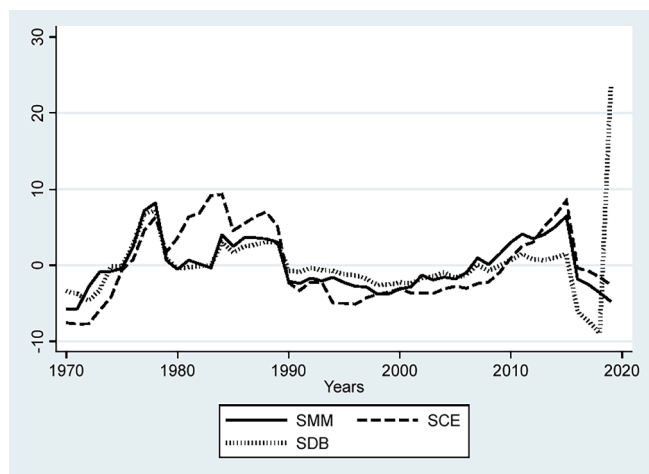


Fig. 1. Financial stability indices.

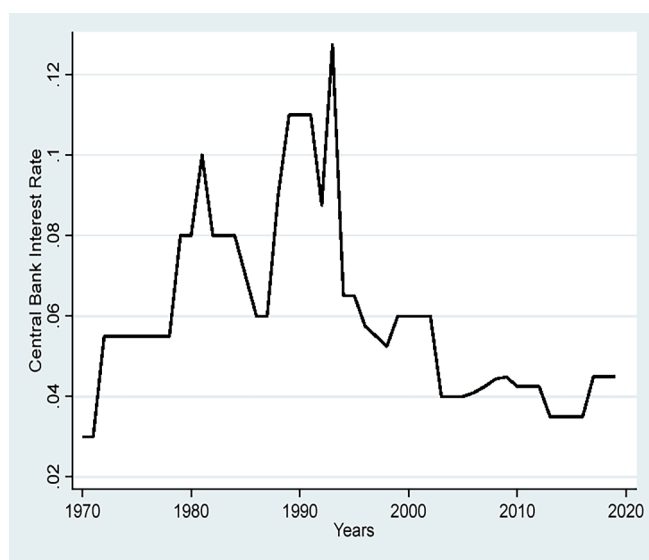


Fig. 2. Central bank interest rate.

Table 1

LSTAR results.

Variable	Coef	St. Dev	t-Stat	Coef	St. Dev	t-stat
Regime-dependent (Linear part)			Regime dependent (Nonlinear part) ISF ≥ 0,419			
ISF < 0,419						
Lag of Central bank interest rate (δ_{01})	0.91*	0.08	10.73	0.25**	0.12	2.02
Inflation gap (δ_{02})	0.29*	0.16	6.43	0.71*	0.40	2.48
Output gap (δ_{03})	-0.48**	0.06	-2.01	0.13	0.08	1.51
Financial stability index (δ_{04})	-0.15	0.02	-0.71	0.804*	0.06	3.00
Regime independent						
u_1	-0.005*	0.006	-2.31			
u_2	-0.083*	0.111	-9.14			
Gamma	120.89*	80.9	2.04			
C	0.419*	0.015	8.78			
R2			0.678			
AIC			-5.645			
SSR			0.006			

***, **, * significance at 10%; 5%; 1%.

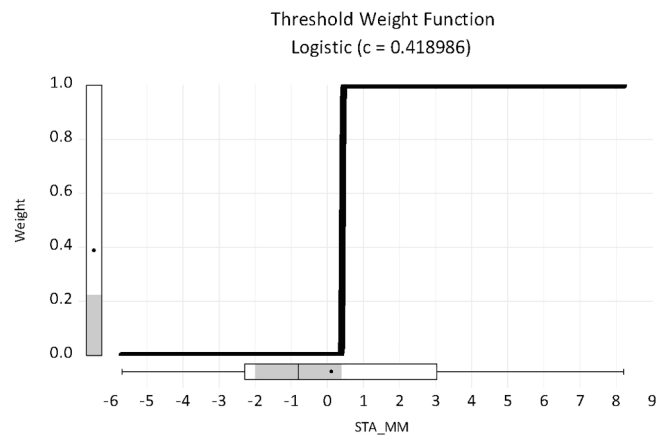


Fig. 3. LSTAR transition function and financial stability.

Sum of Squared Residuals

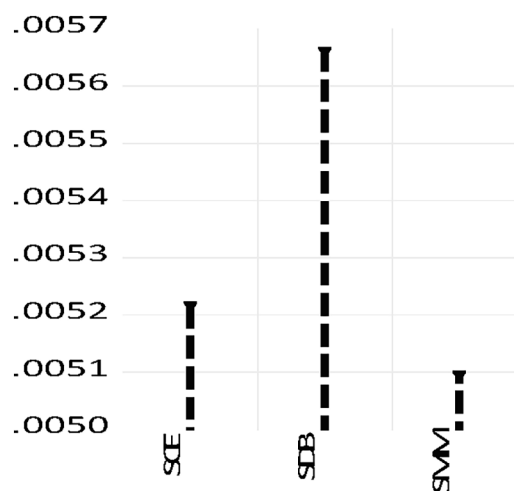


Fig. A1. Choice of the transition variable.

Table A1

Unit root tests.

Variable	Statistic	Critical value (5%)	Decision
Augmented Dickey-Fuller Test (ADF)			
R	-2,404	-3,516	Non stationary
SMM	-2,641	-1,678	Stationary
SCE	-2,081	-1,678	Stationary
SDB	-3,588	-1,678	Stationary
INF	-4,615	-3,504	Stationary
GDP	-3,324	-3,516	Non stationary
Zivot-Andrews Test			
R	-6,394	-5,080	Stationary
SMM	-7,008	-5,080	Stationary
SCE	-6,678	-5,080	Stationary
SDB	-5,362	-5,080	Stationary
INF	-7,192	-5,080	Stationary
GDP	-6,848	-5,080	Stationary

Table A2

Structural break test.

Variable	Statistic	Critical value (5%)	Break date
R	23,384	0,000	1994
GDP	10,164	0,088	1980

Table A3
Optimal lag.

Model	LogL	AIC*	BIC	HQ	Adj. R-sq	Specification
8	12.546	-0.502	-0.419	-0.472	0.742	ARDL (1)
7	12.958	-0.474	-0.350	-0.429	0.741	ARDL (2)
6	13.841	-0.469	-0.303	-0.408	0.745	ARDL (3)
5	13.856	-0.422	-0.215	-0.346	0.734	ARDL (4)
4	14.073	-0.389	-0.136	-0.293	0.738	ARDL (5)
3	14.121	-0.339	-0.049	-0.233	0.727	ARDL (6)
2	14.917	-0.329	0.002	-0.208	0.729	ARDL (7)
1	15.037	-0.287	0.084	-0.151	0.723	ARDL (8)

Table A4
Linearity test.

Null hypothesis	Linearity tests F-statistic	d.f.	p-value
H04: b1 = b2 = b3 = b4 = 0	0.846	(20.24)	0.645
H03: b1 = b2 = b3 = 0	0.939	(15.29)	0.536
H02: b1 = b2 = 0	1.471	(10.34)	0.193
H02: b1 = 0	2.445	(5.39)	0.051

The H0i test uses the i-th order Taylor expansion (bj = 0 for all j > i)

Table A5
Choice between STAR and LSTAR.

Terasvirta Sequential Test			
Null hypothesis	F-statistic	d.f.	p-value
H03: b3 = 0	0.215	(5.29)	0.953
H02: b2 = 0 b3 = 0	0.617	(5.34)	0.687
H01: b1 = 0 b2 = b3 = 0	2.445	(5.39)	0.051

All tests are based on the third-order Taylor expansion (b4 = 0).
Linear model is not rejected at the 5% level using H03.

Table A6
TAR estimates.

Variable	Coef	t-Stat	Coef	t-stat
Regime dependent (Linear part) ISF < 0.481		Regime dependent (Nonlinear part) ISF ≥ 0.481		
Lag of Central bank interest rate (δ ₀₁)	0.902*	13.02	1.151*	13.62
Inflation gap (δ ₀₂)	-0.002	0.43	0.008	1.22
Output gap (δ ₀₃)	-0.080	-1.01	0.081	1.51
Financial stability index (δ ₀₄)	-0.105	-0.91	0.142**	2.320
R2	0.751			
Number of Observations	50			

***,**, * significance at 10%; 5%; 1%.

financial stability have led to divergent results. This paper attempts to complement this empirical literature by referring to the BCEAO framework, which lends itself well to this exercise.

3. Methodology

3.1. Model

Recent literature on the modeling of central banks' reaction function is generally based on the conventional framework of the Taylor rule. Starting from the limitations of the initial version of the Taylor rule to reflect the behaviour of the central bank, a vast literature has subsequently developed which suggests the inclusion of other variables in its reaction function. From this moment on, the augmented Taylor rule

appeared. Among the empirical works that have adopted such an approach to the augmented Taylor rule are the works of Ténou (2002), Zhua and Chend (2017), and Hounghbedji (2022).

While monetary policy may have many goals that may be in conflict, Taylor's rule has the potential to simultaneously take into account these goals by affecting a certain weight to each objective. A simple reaction function of central banks is used to adjust the short-run interest rate. Then, we modify the conventional Taylor rule by adding financial stability as follows:

$$R_t = \mu + \omega R_{t-1} + \beta_1 (\pi_{t+k} - \pi^*) + \beta_2 (Y_{t+k} - Y_{t+k}^*) + \beta_3 (F_{t+k} - F_{t+k}^*) + \varepsilon_t \tag{1}$$

In equation (1), R denotes the central bank interest rate at period t, π_t is the inflation rate, and π* is its target value. Y_{t+k} - Y*_{t+k} is the output gap, F_{t+k} - F*_{t+k} is the deviation of the financial stability index, and t is the time operator. β are the monetary policy reaction function parameters to be estimated. For simplification, the following notations are adopted:

3.2. Estimation methods

The threshold autoregressive model (TAR) developed by Tong (1990) and Tsay (1989) may be considered the root of nonlinear time series modeling. TAR models are an extension of autoregressive time series models by allowing the parameters of the model to vary according to the values taken by an exogenous variable, called the transition or threshold variable. The basic form of the TAR model is specified as:

$$r_t = \begin{cases} \beta_{10} + \beta_{11}r_{t-p} + u_{1t} & \text{si } s_t < r \\ \beta_{20} + \beta_{21}r_{t-p} + u_{2t} & \text{si } s_t \geq r \end{cases} \tag{2}$$

where r is the dependent variable, p is the number of optimal lags of the dependent variable, β_i are the parameters to be estimated for each regime i, s is the transition variable and r is the estimated threshold allowing the transition from regime 1 to regime 2.

To account for smooth monetary policy behaviour, we adopt a Smooth Threshold Autoregressive (STAR) model developed by Granger and Teräsvirta (1993) and Teräsvirta, 1998. The STAR models are TAR models that allow a smooth transition (continuous) from one regime to another.

The basic form of the STAR model with two regimes can be defined as:

$$r_t = [1 - G(s; c; \gamma)]X'_t\delta_0 + G(s; c; \gamma)X'_t\delta_1 + \varepsilon_t \tag{3}$$

r is the dependent variable, X is the vector of explanatory variables including the lagged variable of the dependent variable, and G is the Heaviside-type transition function, which is defined as:

$$\forall x \in R, H(x) = \begin{cases} 0 & \text{if } x < 0 \\ 1 & \text{if } x > 0 \\ \text{indefinite} & \text{if } x = 0 \end{cases}$$

s defines the transition variable, c is the estimated threshold of the transition variable(s), and γ is the speed of the transition from one regime to another. ε is an independently and identically distributed error term iid, with zero mean and finite variance. The choice of a STAR model instead of an STR (Smooth Transition Regression) model developed by Terasvirta (2004) is justified by our theoretical framework. Indeed, Taylor's rule introduces the lag in the key central bank interest rate as an explanatory variable in the monetary policy reaction function.

The estimation of the STAR model is conditioned on the specification of the distribution of the transition function G (.). The distribution can be either a logistic or an exponential function (Teräsvirta, 1994). The logistic form of the transition function G (.) is:

$$G(s_i; c; \gamma) = [1 + \exp\{-\gamma(s_i - c)\}]^{-1} \tag{4}$$

where $G(\cdot)$ is a real parameter that takes values between 0 and 1. The exponential function of $G(\cdot)$ is defined as:

$$G(s_i; c; \gamma) = 1 - \exp\{-\gamma(s_i - c)^2\} \tag{5}$$

From equations (4) and (5), we can derive the LSTAR and ESTAR models, respectively, by replacing equations (4) and (5) in equation (3) with the following implications:

- i) If $\gamma \rightarrow \infty$, then, $G(\cdot) = 0$ when $s_i \leq c$ and $G(\cdot) = 1$. Hence, the STAR model is simply equal to the TAR model described in equation (2).
- ii) In contrast, if $\gamma \rightarrow 0$, the STAR model becomes a simple linear autoregressive model (AR).

We estimate the LSTAR and ESTAR models through the nonlinear least-squares method including the parameters γ and c . However, to make easy the estimation of γ , [Teräsvirta \(1994\)](#) suggests the normalization of the function $G(\cdot)$ by the standard deviation of the transition variable s as:

$$G(s_i, \gamma, c) = \left[1 + \exp\left\{ -\frac{\gamma}{\sigma_{s_i}}(s_i - c) \right\} \right]^{-1} \tag{6}$$

Finally, the empirical model of the BCEAO reaction function to be estimated is:

$$r_t = [1 - G(\cdot)]r'_{t-1}\delta_{01} + G(\cdot)r'_{t-1}\delta_{11} + [1 - G(\cdot)]i'_t\delta_{02} + G(\cdot)i'_t\delta_{12} + [1 - G(\cdot)]y'_t\delta_{03} + G(\cdot)y'_t\delta_{13} + [1 - G(\cdot)]f'_t\delta_{04} + G(\cdot)f'_t\delta_{14} + \varepsilon_t \tag{7}$$

where $G(\cdot) = G(f_t; c; \gamma)$.

Furthermore, it is worth noting that, in equation (7), the inflation gap and the output gap (the economic cycle) are endogenous (Kim, 2009). We solve this problem using a two-step estimation method as employed by Kim and Nelson (2006). Consequently, the equations of the inflation gap and that of the output gap are instrumented in the first step as follows:

$$i_t = \alpha_{1t}h_{it} + u_{1t}, \quad \forall u_{1t} \sim i.i.d \ N(0, \sigma_{u_{1t}}^2) \tag{8.1}$$

$$y_t = \alpha_{2t}h_{yt} + u_{2t}, \quad \forall u_{2t} \sim i.i.d \ N(0, \sigma_{u_{2t}}^2) \tag{8.2}$$

Where h_t is a vector of instruments (the lagged values of the explained variables) and α_{1t} and α_{2t} are the parameters to be estimated. In the second step, the residuals resulting from the estimation of equations (8.1) and (8.2) are introduced into equation (7).

Finally, the estimation of the parameters of the STAR model consists of three steps:

Step 1: Determining the optimal lag of the dependent variable through the estimation of an AR (p) model. The optimal lag (p) is chosen through the information criteria Akaike information criterion (AIC) and Bayesian Information Criterion (BIC).

Step 2: Use the [Luukkonen, Saikkonen, and Teräsvirta \(1988\)](#)'s approach by replacing the transition function $G(\cdot)$ of equation (7) with the first-order Taylor approximation around $\gamma = 0$, we obtain the auxiliary regression as:

$$z_t = x'_t b_0 + (x'_t s_t) b_1 + \varepsilon_t \tag{9}$$

The null hypothesis of the test is $H_0: b_1 = 0$

Step 3: Choosing the best model between LSTAR and ESTAR by constructing a joint sequence of hypothesis tests based on the auxiliary regression obtained from equation (10). The third-order Taylor approximation is used and leads to:

$$z_t = x'_t b_0 + (x'_t s_t) b_1 + (x'_t s_t^2) b_2 + (x'_t s_t^3) b_3 + \varepsilon_t \tag{10}$$

The following null hypotheses are formulated:

$$\begin{aligned} H_{03} : b_3 &= 0 \\ H_{02} : b_2 &= 0 | b_3 = 0 \\ H_{01} : b_1 &= 0 | b_2 = b_3 = 0 \end{aligned} \tag{11}$$

The LSTAR model is chosen when null hypotheses 1 or 3 are strongly rejected; otherwise, the ESTAR model is the best.

3.3. Data and sources

We use yearly aggregated data covering 1970 to 2020 and the eight (08) WEMUA countries (Benin, Burkina Faso, Ivory Coast, Guinea Bissau, Mali, Niger, Senegal, and Togo). The choice of the study period is constrained by the availability of data. In addition, the use of yearly data instead of monthly or quarterly data is due to the unavailability of monthly or quarterly data for the study variables in the sample. The BCEAO interest rate data come from the BCEAO website. The output gap is measured by the ratio of the deviation of real GDP to that of potential GDP obtained using the Hodrick-Prescott filter over the potential level of real GDP as: $(GDP - GDP_{hp})/GDP_{hp}$. The target inflation rate is the average inflation rate calculated in the study.

The measurement of financial stability is subject to debates justifying the multiplicity of indicators used. Financial stability is generally measured by indicators such as the z-score, the non-performing loan ratio, and the quality of financial regulation...). In order to take this multidimensionality into account, a composite index of financial stability has been used recent years. This index was used by [Gbénou and Amoussouga Géro \(2017\)](#) and confirmed the reliability of the index in the WAEMU zone. However, for reasons of the availability of these different indicators over our study period, the present study privileges another alternative. To this end, and following [Guillaumont \(2006\)](#), we retain three financial sector indicators to capture financial development from which the financial stability indicator is derived.

Financial stability is measured by the variance of the cyclical component of the financial development indicator captured by three ratios (Bank deposit/GDP; Money supply/GDP, Credit to the economy/GDP). The cyclical component is equal to the difference between the financial development indicator and its long-term trend. Thus, by denoting FDI as the financial development indicator, CC as its cyclical component, and TC as its trend component, we have:

$$CC_t = FDI_t - TC_t \tag{13}$$

The financial stability index (hereafter, FSI) is determined by the variance of the cyclical component (CC) stress as follows:

$$F_t = [CC_t - Me(CC)] \tag{14}$$

Where $Me(CC)$ is the median value of CC. To make the comparison easier, the FSI computed is normalized and takes values between 0 and 1, with 0 indicating strong financial stability and 1 indicating a strong risk of financial instability. Our results indicate that the average values of the financial index in the sample are approximately 0.413 when computed through the money supply ratio, 0.453 for the credits to economy ratio, and 0.475 for the bank credit ratio.

The determination of the trend component (TC) depends on the assumption of whether it is linear, determinist, stochastic, mixed, or moving averages. This trend component is extracted using a filter whose algorithm is based on weighted moving averages. The Hodrick and Prescott (1980) filter is used to determine the trend component.

In the rest of this work, the financial stability is calculated using the ratio of credit to the economy (hereafter, SCE), that of the ratio of the money supply (hereafter, SMM), and SDB are computed from the Bank deposit. The data come from the BCEAO database and the World Development Indicators.

4. Results and discussion

Let this section begin by presenting the dynamics of the financial stability indices computed as described in the data section (Fig. 1) and that of the interest rate of the BCEAO (Fig. 2).

First, it can be seen from Fig. 1 that all three financial stability indices (SMM, SCE, and SDB) have the same trend over the study period. Second, between 1970 and 1990, the central bank interest rate (Fig. 2) and the financial stability indices moved in the same direction, reflecting an increase in the central bank interest rate with high volatility in financial stability indices. However, it emerges from the analysis of Figs. 1 and 2 that the central bank interest rate has evolved in the opposite direction to the evolution of the financial stability indices since the 2000s. In sum, the descriptive analysis is inconclusive on the central bank's reaction to financial stability. An econometric model is then more suitable.

Furthermore, time series modeling requires stationary variables. Thus, the Zivot and Andrews (1992) unit root test with structural breaks indicates that all our series are stationary (Table A1 in the Appendix). Indeed, the use of this unit root test is based on the existence of structural breaks for some of our series (Table A2 in the Appendix).

2.1. Optimal lag AR (p) and transition variable

The results reported in Table A3 (Appendix) show that the first-order AR (1) is the best model by minimizing the information AIC, BIC, and HQIC criteria. We then estimated the STAR (1) model as specified in equation (7) with the three different indicators of financial stability. The results indicate that the SMM index is the best transition variable by recording the lowest values of the sum of the squares of the residuals (Fig. A1 in the Appendix).

2.2. Linearity test and best STAR model.

The first fundamental step in estimating threshold models is to perform the linearity test. The results of the linearity test of Luukkonen et al. (1988) presented in Table A4 in the Appendix show that the null hypothesis of linearity is rejected at the 5% level of significance, indicating that the BCEAO reaction function is nonlinear. Likewise, the discrimination test between the LSTAR and ESTAR models indicates that the LSTAR model is suitable for our data. Indeed, the p-value associated with hypothesis H1 is the smallest (Table A5 in the Appendix).

2.3. LSTAR estimates

The results from the estimation of the LSTAR model presented in Table 1 show that the coefficients u_1 and u_2 are all significant at the 1% level, supporting the fact that we handled the endogeneity issue in the model.

These results also indicate that the estimated threshold of the SMM is 0.419 with a transition speed from the low to the high regime of 120.89. This threshold falls into the span of our financial stability index, which ranges between -5.76 and $+8.2$.

Thus, the BCEAO reacts to a risk of financial stress if the financial stability index exceeds a threshold of 0.419. This result is attested by the significant coefficient of the SMM in the second regime at the 1% level of significance. In particular, a 10% increase in the financial stability index leads to an increase in the BCEAO interest rate by 8.04% when financial stability is beyond the value of 0.419. Our results confirm those of Fouejieu (2014). Indeed, from his study on a sample of emerging countries, the author found that monetary authorities adopt restrictive monetary policies in reaction to financial stress. However, Floro and van Roye (2017) showed that the monetary authorities in emerging countries react to financial stress only in the low regime. For high values of the financial stability index, the reaction of central banks in emerging countries becomes ineffective. This result is in line with those of

Dibooglu et al. (2020) in US.

Furthermore, the significance of the two regimes of the lagged interest rate implies that the BCEAO conducts monetary policy by taking into consideration its previous strategies. This result reflects a high degree of inertia in monetary policy that the BCEAO has. Thus, the monetary policy in the WEAMU region anchors the expectations of economic agents to the extent that the modification of the central bank interest rate rarely occurs, especially when the financial stability index is below 0.419. Therefore, economic agents could be confident in the conduction of monetary policy by the BCEAO.

The coefficients of inflation and that of the output gap also show that the BCEAO reacts permanently to inflation pressures regardless of the regime, whereas it reacts to a deviation of the output gap only in economic recessions. In particular, the BCEAO adopts a restrictive monetary policy to tackle inflation with a violent reaction in the high regime, i.e., when the financial stability index is beyond 0.419.

The negative and significant coefficient of the output gap in the low regime indicates that the BCEAO adopts accommodating monetary policies in recessions rather than economic expansions. This result confirms that the BCEAO is loyal to the main goal of price stability to which it is mandated. Our findings are in line with those found by Haddou (2010) in Tunisia.

Furthermore, Fig. 3 presents the transition function of the LSTAR model estimated as a function of the financial stability index. From the analysis of this figure, it appears that the speed of transition from a low to a high regime seems to be fast, suggesting the estimation of a non-smooth model.

In this regard, we check for robustness by using the TAR model. Without any objection, the results indicate that there is no significant difference between the TAR and STAR estimates.

In particular, the TAR results estimated a threshold financial stability index of 0.481, which is closer to that of 0.419 obtained from the STAR specification (Table A6 in the Appendix).

5. Conclusion

The objective of this article is to highlight the nonlinearity of the reaction function of the BCEAO through a financial stability index. Using the threshold effect model with a smooth transition (Smooth Threshold Autoregressive, STAR), we found that the dynamics of monetary policy are conditioned on the financial stability index in the WEAMU region. In particular, the null hypothesis of symmetric reactions in conducting monetary policy is strongly rejected in favour of asymmetric behaviours. Thus, the BCEAO reacts to a risk of financial instability if the volatility of the financial stability index exceeds a threshold of 0.419. In particular, the BCEAO adopts a restrictive monetary policy by raising its interest rate by 8.04% for an increase of 10% in the financial stability index, when this latter is beyond the value of 0.419. However, in low regimes of the financial stability index, the BCEAO remains insensitive. These findings are robust to the alternative specification from the threshold autoregressive model (TAR).

Our findings lead to some implications. On the scientific side, the financial stability index used in this study needs to be tested in further research. More importantly, we omitted the role of unconventional monetary policy and also used monthly data in the modelling of the BCEAO's reaction function. It would be interesting for further studies to explore these different avenues in the understanding of the non-linearity of the BCEAO reaction function. Practically, considering the dynamics of the cyclical component of the money supply to GDP ratio in conducting monetary policy, our findings suggest that the BCEAO should take into account the reaction function. This could prevent the risk of financial instability in the WEAMU region. Two points should be highlighted when using the present findings.

CRedit authorship contribution statement

Honoré S. Hounghédji: Conceptualization, Writing – original draft, Writing – review & editing, Supervision. **Nassibou Bassongui:** Data curation, Methodology, Software, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix

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