E C O N O M I C S   B U L L E T I N

Exchange Rate Volatility and Optimum Currency Area: Evidence from Africa

Chrysost Bangaké
Department of Economics, LEO, University of Oleans (France)

Abstract

In this paper we use a system of simultaneous equations and Generalized Method of Moment (GMM) to investigate the relation between bilateral exchange rate volatility and the relevant variables pointed out by the theory of optimum currency areas (OCA) for 21 selected African countries for the period 1990-2003. The evidence turns out to be strongly supported by the data. An OCA index for African countries is derived by adapting a method initially proposed by Bayoumi and Eichengreen (1997). The results have important policy implications for proposed monetary unions in Africa.

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1. Introduction

Since the work of Meese and Rogoff (1983), it is generally admitted that movements in exchange rates are largely unpredictable. Understanding what drives bilateral exchange rate volatility across countries has been of special interest to researchers. Bayoumi and Eichengreen (1998) point out that exchange rate volatility could be explained by the relevant OCA variables that have been used in the literature[1], such as the difference in economics shocks, the trade links, the dissimilarity of the composition of the exports and country size. In addition to the standard set of Optimum currency area (OCA) variables, Devereux and Lane (2003) also consider a series of financial variables and use a sample of developing and industrial countries.

Unfortunately, to the best of our knowledge, no study has directly addressed the relation between bilateral exchange rate volatility and the variables used in the standard literature on OCA in the African context.

This empirical study contributes to this line of research by determining whether the variables elaborated by the theory of OCA help to explain the behaviour of bilateral exchange rate in the case of Africa. We empirically examine the relation between bilateral exchange rate volatility and OCA variables for 21 African countries using a system of simultaneous equations and generalized method of moments (GMM). The evidence turns out to be strongly supported by the data. An OCA index for African countries is derived by adapting a method initially proposed by Bayoumi and Eichengreen (1997). The results have important policy implications for proposed monetary unions in Africa.

The remainder of the paper is organized as follows. Section 2 describes the data and the empirical approach used to study the relation between bilateral exchange rate and variables used in standard literature of OCA. Section 3 discusses the main findings and robustness. The section 4 presents OCA index for African countries. Finally, section 5 summarizes our findings and concludes.

2. Data and empirical methodology

2.1 Data

The main focus of this study is the relation between bilateral exchange rate volatility and variables used in the standard literature of OCA. These variables are: asymmetric disturbances to output, dissimilarity of the commodity composition of export, trade linkages, and size. The bilateral exchange rate volatility is measured by the standard deviation of the change in the logarithm of bilateral nominal exchange rate between country *i* and *j*. This is constructed using monthly data over 1990-2003. The asymmetric disturbances to output variables (AC_{ij}) is computed as the standard deviation of the difference in the logarithm of real output between *i* and *j*. Following Bayoumi and Eichengreen (1997, 1998), the dissimilarity of the commodity composition of export ($DISSIM_{ij}$) is measured by the sum of the absolute differences in the shares of agricultural, mineral, and manufacturing trade in total merchandize trade. Trade linkages ($TRADE_{ij}$) is the mean of the ratio of bilateral exports to domestic GDP for the two countries. $SIZE_{ij}$ is the mean of the logarithm of the two GDPs measured in U.S. dollars. The former variable is introduced to account for the benefits of exchange rate stability: smaller countries should be reluctant to tolerate fluctuations in the

[1] The literature on OCA was initiated by Mundell (1961).

nominal exchange rate. The AC_{ij}, $DISSIM_{ij}$, $TRADE_{ij}$, and $SIZE_{ij}$ variables are constructed using annual data.

Data on the exchange rate, real GDP and bilateral trade data is taken from the International Monetary Fund (IMF)[2]. The $DISSIM_{ij}$ variable is calculated by using the data provided by COMTRADE[3]. The analysis is carried out on a sample of 21 selected African countries over the 1990-2003

2.2 Empirical methodology

Our empirical specification consists of modelling the exchange rate volatility by

$$VOL_{ij} = \beta_0 + \beta_1 AC_{ij} + \beta_2 DISSIM_{ij} + \beta_3 TRADE_{ij} + \beta_4 SIZE_{ij} + \mu_{ij} \qquad (1)$$

Our main interest lies in the signs and the magnitude of the $\beta_1, \beta_2, \beta_3$, and β_4 coefficients. We expect that the exchange rate volatility positively depends on the business cycle and on the dissimilarity in the commodity structure of exports ($\beta_1 \succ 0, \beta_2 \succ 0$), and negatively on the trade linkages $\beta_3 \prec 0$. The expected sign of the size $\beta_4 \succ 0$.

3. Results

3.1 Descriptive statistics

Table 1 reports summary statistics for key variables (full sample). As we can see in table 1 the mean and standard deviation of exchange rate volatility is relatively higher around 5%. The high volatility of exchange rates in the 1990s was probably caused by large depreciation and devaluation of African currencies.

For the variable symmetric of shocks to production (AC), the mean and standard deviation are around 6%, higher comparing to industrial countries sample used by Bayoumi and Eichengreen (1997). If the business cycle were fully synchronised, the value would 0.

The most striking feature of this table is the degree of specialisation of African countries, illustrated by a higher propensity for asymmetric shocks with the variable dissimilarity of export (DISSIM) for full sample around 41%. This result is not surprising, Bayoumi and Ostry (1996) show that the majority of African countries are highly specialised in the production and export of a few primary commodities[4].

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[2] Bilateral Trade data is drawn from IMF Direction of Trade.

[3] To construct this variable, following Bayoumi and Eichengreen (1998), we collected data on the shares of manufactured goods, food and minerals in total merchandise trade for each country using Standard International Trade Classification 1-digit (SITC1) provided by COMTRADE. There are nine sectors. Sector 0: Foods and animals chiefly. Sector 1: Beverages and Tobacco. Sector 2: Crude materials, inedible, except fuels. Sector 3: Mineral fuels, lubricant and related materials. Sector 4: Animal and vegetable oils, fats and waxes. Sector 6: Manufactured goods classified chiefly by materials. Sector 7: Machinery and transport equipment. Sector 8: Miscellaneous manufactured articles. Sector 9: commodities and transactions not classified elsewhere. We group manufactured goods as being: sectors 5+6+7+8+9. Food contains sectors 0+1+4. Minerals contain sectors 2+3.
We also use World Trade database to complete missing data. Because of the differences in the classification system, a harmonization was imperative.

[4] See also Masson and Patillo (2004)

Table 1: Summary statistics

	VOL	DISSIM	AC
Mean	0.057	0.430	0.068
St. Deviation	0.041	0.217	0.066
N	210	210	210

3.2 Empirical results

3.2.1 OLS Estimation

We begin with a basic specification OLS. The columns (1) and (3) show our OLS estimates of equation (1) for different measures of bilateral trade (normalized by total trade and output for all country pairs, respectively).

In the column (1), we conduct OLS regression when the trade intensity is normalized by total trade. The Standard OCA variables work reasonably well. The signs of all coefficients are as predicted. Consistent with our intuition, the bilateral exchange rate volatility is explained by the standard variables of OCA. Our OLS estimates show a positive and significant association between dissimilarity of the commodity composition of exportation (DISSIM), business cycle (AC) and exchange rate volatility at the 1% level. The coefficient estimates on TRADE exhibit a negative sign and is statistically significant at 1% level. The African countries that trade intensively have more stable exchange rates. However, the coefficient estimate of SIZE is positive and significant at 10% level. These results are robust to changes in the measure of trade intensity (column 3) precisely when we run our OLS regression using trade intensity normalized by total output for all country pairs. This is consistent with the findings of Bayoumi and Eichengreen (1997) for 21 OECD countries and those of Devereux and Lane (2003) for industrial and developing countries.

3.2.2 IV Estimation

The estimation of equation 1 by OLS regressions may be misleading if some of the independent variables are endogenously determined by the level of bilateral exchange rate volatility. *Trade*, *Cycle* could be potentially affected by this problem. We need instruments for *Trade* and *Cycle* in order to estimate the equation (1) consistently. Our instruments for these variables are : $DISTANCE_{ij}$, $BORDER_{ij}$, $LANGUAGE_{ij}$, $COLONIZER_{ij}$, $SIZE_{ij}$ and DISSIM; where $DISTANCE_{ij}$ is the logarithm of bilateral distance between countries *i* and *j*. $BORDER_{ij}$ is a dummy variable which takes the value of 1 if the two countries share a common border and 0 otherwise. $LANGUAGE_{ij}$ and $COLONIZER_{ij}$ are dummies variables too. $LANGUAGE_{ij}$ =1, if countries *i* and *j* have the same language and 0 for the other remaining country-pairs. $COLONIZER_{ij}$ =1, if two countries have the same colonizer and 0 otherwise. $SIZE_{ij}$ is the size between the two countries. Bayoumi and Eichengreen (1998), Devereux and Lane (2003), Calderon and alii (2003) use the similar list in instrumenting for Trade and Cycle[5].

[5] Shea (1997) proposes a methodogy to investigate the relevant of instruments list. However, he does not provide a formal methodology for establishing a threshold level of acceptability for the partial R^2 value.

We check for the endogenity by estimating the following system of simultaneous equations:

$$VOL_{ij} = \beta_0 + \beta_1 TRADE_{ij} + \beta_2 DISSIM_{ij} + \beta_3 AC_{ij} + \beta_4 SIZE_{ij} + \mu_{ij} \tag{1}$$

$$\begin{aligned} TRADE = \alpha_0 + \alpha_1 SIZE_{ij} + \alpha_2 DISTANCE_{ij} + \alpha_3 BORDER_{ij} \\ + \alpha_4 COLONIZER_{ij} + \alpha_5 LANGUAGE_{ij} + \alpha_6 DISSIM + \varepsilon_{ij} \end{aligned} \tag{2}$$

$$\begin{aligned} AC = \phi_0 + \phi_1 SIZE_{ij} + \phi_2 BORDER_{ij} + \phi_3 LANGUAGE_{ij} \\ + \phi_4 TRADE_{ij} + \phi_5 DISTANCE + \phi_5 DISSIM + \tau_{ij} \end{aligned} \tag{3}$$

Our system of simultaneous equations is estimated by iterative GMM. It contains 3 equations and 7 instruments[6] therefore 21 orthogonal conditions to estimate 19 parameters. The system is overidentified. The method of numeric optimization used by SAS software is that suggested by the Gauss Newton process.

It should noted that the J-statistic of Hansen is 0.12. The J-statistic is typically insignificant, implying that the overidentifying restrictions tests are not rejected[7]. The IV results are given in columns (2) and (4). Standard OCA variables work reasonably well. Exchange rate volatility is determined by the conventional OCA variables. Our results are broadly similar to those found in OLS regression.

However, unlike the OLS results, the impact of our coefficients of interest appears somewhat larger in magnitude. In column (2), we note that the magnitude of the coefficient estimates for Trade, Size, are increased, and all coefficient estimates are significant at the level 1%. While the coefficient estimate on size seems to become weaker when the OLS regression is used, the GMM procedure improves this significant. These results are robust to changes in the measure of trade intensity (column 4) precisely when we run our IV regression using trade intensity normalized by total output for all country pairs

[6] Another instrument is the constant

[7] The test of identifying for $r \succ a$ is given by $J = \left[\sqrt{T_g}(Y_T, \hat{\theta}_T)\right]' S^{-1} \left[\sqrt{T_g}(Y_T, \hat{\theta})\right] \xrightarrow{L} \chi^2(r-a)$

Table 2: Volatility regressions, OLS and IV Estimations

	OLS (1)		IV-GMM (2)		OLS (3)		IV-GMM (4)	
C	-0.022		-0.065		-0.021		-0.067	
	(-0.73)		(-1.70)*		(-0.71)		(-1.79)*	
TRADE	-3.790		-4.896		-3.774		-5.406	
	(-3.35)***		(-4.89)***		(-3.10)***		(-4.72)***	
AC	0.120		0.235		0.118		0.245	
	(2.91)***		(2.88)***		(2.86)***		(3.04)***	
DISSIM	0.052		0.046		0.0529		0.048	
	(4.26)***		(3.40)***		(4.29)***		(3.57)***	
SIZE	0.0031		0.005		0.0030		0.005	
	(1.76)*		(2.70)***		(1.72)*		(2.74)***	
	R^2	0.17	J-statistic	0.12	R^2	0.16	J-statistic	0.12
	N	210	N	210	N	210	N	210

***, **,* denote 1%, 5% and 10% levels of significance.
Columns (1)-(2) show OLS and IV estimations when the ratio of bilateral exports to total trade flows is used as Trade Intensity index. Columns (3)-(4) present OLS and IV estimations when the ratio of bilateral exports to domestic GDP for the two countries is used. OLS and IV estimations, with White-corrected standards errors. *t*-statistics in parentheses.

4. OCA index for African countries

Following the methodology initiated by Bayoumi and Eichengreen (1997), we use equation (1) of our system of equations (GMM procedure, table 2) to derive OCA index for African countries in 2003. The lower value of OCA index suggests that the countries are "good" candidates to join a currency union.

We are interested in different economic grouping in Africa. Table 3 presents the OCA index for all countries: The CFA franc zone; the Economic Community of West African countries (ECOWAS, a broader grouping of West African Countries); the Southern African Development Community (SADC); the Common Market for Eastern and Southern Africa (COMESA).

Concerning the CFA franc zone (table 3), we can distinguish two cases. For the West African Economic and Monetary Union (WAEMU), the OCA index is generally low reflecting the structural convergence between these countries. This is the case for Benin, Ivory Cost, Mali, Burkina, Senegal, and Togo… In most cases OCA index is below 3%, the threshold proposed by Bayoumi and Eichengreen (1997) implying the viability of this community. However, for the Central African Economic and Monetary Community (CAEMC), the values of the OCA index are high. Particularly, Gabon and Cameroon show high predicted volatility. It is the same case for Central Africa Republic and Gabon, indicating that these countries pairs are structurally different. This result indicates that CAEMC cannot be viewed as an optimum currency area.

For ECOWAS (table 4), Ghana, non CFA country, exhibits a structural convergence vis-à-vis Ivory Coast, Togo, and Benin. This result suggests that the inclusion of Ghana in extended UEMOA would be appropriate. However, the predicted volatility for Nigeria related to others ECOWAS countries is higher. This result suggests that the inclusion of Nigeria in the West African Monetary Zone (WAMZ) or in the extended WAEMU is not suitable according to the OCA theory. The result is consistent with those obtained by Bénassy-Quéré and Coupet (2003). These authors used cluster techniques and found similar results. They concluded that the “the creation of the WAMZ around Nigeria is not supported by the data”. Contrarily to these authors, we present evidence that OCA index is not a lot higher vis-à-vis Ivory Coast. It seems that bilateral trade intensity between these two countries could explain this finding. Yehoue (2005) used the trade criteria and shows that Ivory Coast and Niger are good candidates for joining Nigeria.

For SADC countries (table 5), a reasonable structural convergence exists among the following countries: Malawi, Zambia and Zimbabwe. This suggests that a monetary union that encompasses these countries would not suffer high costs. Our results contrast to recent research by Khamfula and Huizinga (2004) in which they stress the viability of a monetary union in SADC including Malawi, South Africa, Mauritius and Zimbabwe.

A highly interesting finding concerning COMESA (table 6) is that the old East African Community, Kenya, Uganda and Tanzania exhibit similar structural characteristics. The implementation of the currency union in this part of Africa would be successful according to our empirical model. This finding is consistent with Mkenda (2001). Indeed, Mkenda applies the cointegration technique to assess the suitability for East African Community to form a monetary union.

5. Summary and conclusions

In this paper, we examined the relationship between bilateral exchange rate volatility and the relevant variables of OCA by studying a sample of Sub-Saharan African countries. By using a system of simultaneous equations and the GMM technique, we provide the evidence concerning the link between bilateral exchange rate volatility and variables such as: size, trade intensity, sector-specific shock and disturbance to output. Then, we derived an OCA index for African countries. The results have important policy implications for proposed monetary unions in Africa (CEDEAO, COMESA and SADC)

References

Bayoumi T., and J. Ostry (1996) « Macroeconomic Shocks and Trade Flows within Sub-Saharan Africa: Implication for Optimum Currency Arrangements » *Journal of Africa Economies*, **6**, Number 3.

Bayoumi T., and J. Eichengreen (1997a) « Ever closer to Heaven? An optimum currency area Index for European countries » *European Economic Review*, **41**, 761-770

Bayoumi T & J. Eichengreen (1998) « Exchange rate volatility and intervention: implications of the theory of optimum currency areas » Journal of International Economics, pp 191-209.

Benassy-Quéré, A., and M. Coupet (2003) « On the Adequacy of monetary arrangements in Sub-Saharan Africa » *CEPII*, document de travail n°2003-11.

Calderon C., A. Chong., and E. Stein (2003) « Trade Intensity and Business cycle synchronisation: Are developing countries any different? », *Inter-American Development Bank, Working Paper*, **478.**

Devereux M., and P. Lane (2003) « Understanding Bilateral Exchange Rate Volatility », *Journal of International Economics,* **60**, 109-132

Masson P., and C Patillo (2004), *The Monetary Geography of Africa*, Brookings Institution Press, Washington, D.C

Meese R., and K. Rogoff (1983) « Empirical exchange rate models of the seventies: do they fit out of sample. » *Journal of International Economics* **14**, 3-24

Mkenda B. (2001) « Is East Africa an optimum currency area? » *Working Papers in Economics,* 41, Göteberg University.

Mundell R (1961) « A theory of optimum currency areas » *American Economic Review, November*, 509-517

Yehoué E. (2005) « On the pattern of currency blocs in Africa » *IMF working paper* WP/05/45

Appendix 1: GMM principle

Consider a model of standard regression:

$$y_t = z'_t \beta_0 + u_t$$

where z_t is defined as a vector of dimension $(k,1)$. Assume that certain independent variables are endogenous $E(z_t u_t) \neq 0$. Designated by x_t a vector $(r,1)$ of predetermined explanatory variables, correlated to z_t but not correlated to residual u_t such $E(x_t u_t) = 0$. If we put that $w_t = (y_t x'_t\, z'_t)'$ and $\theta = \beta$, $a = k$, this constraint gives r orthogonal conditions :

$$\underset{(r,1)}{E[h(\theta_0, w_t)] = E[x_t(y_t - z_t'\beta_0)] = 0}$$

where $h(\theta_0, w_t) = x_t(y_t - z_t'\beta)$. Consider $g(Y_T, \theta)$ the vector of empirical moments corresponding to r orthogonal conditions:

$$g(Y_T, \theta) = \frac{1}{T}\sum_{t=1}^{T} h(\theta, w_t) = \frac{1}{T}\sum_{t=1}^{T} x_t(y_t - z_t'\beta)$$

Designate by $\hat{\theta}_T = \hat{\beta}_T$; the GMM estimator $\hat{\theta}$ is obtained by minimizing the following loss function:

$$Q(\theta, Y_T) = [g(Y_T, \theta)]'\hat{S}_T^{-1} g(Y_T, \theta)$$

where $\hat{S}_T$ is an estimator of $S = \lim_{T\to\infty} \frac{1}{T}\sum_{t=1}^{T}\sum_{v=-\infty}^{\infty} E[h(\theta_0, w_t)h(\theta_0, w_{t-v})']$

Computing the variance-covariance matrix of $\hat{\beta}$ and using the result of Hansen (1982), we have

$$\hat{\theta} \cong N\left(\theta_0, \frac{\hat{V}_t}{T}\right) \text{ where } \hat{V}_T = \left[\hat{D}\hat{S}_T^{-1}\hat{D}'\right]^{-1} \text{ and } \hat{D}' = \left.\frac{\partial g(Y_T, \theta)}{\partial \theta'}\right|_{\theta = \hat{\theta}_T}$$

Table 3: OCA index for CFA Countries, 1990-2003

	BEN	BURK	CAM	CIV	GAB	ML	NG	RCA	SEN	TG
BEN										
BURK	**0,020**									
CAM	0,040	0,042								
CIV	0,036	**0,000**	0,049							
GAB	0,047	0,051	0,047	0,065						
ML	**0,029**	**0,023**	0,046	**0,009**	0,062					
NG	**0,029**	**0,028**	0,039	**0,027**	0,055	0,037				
RCA	**0,028**	**0,027**	0,034	0,045	0,052	0,032	**0,027**			
SEN	0,031	0,037	0,038	**0,022**	0,058	**0,008**	0,035	**0,028**		
TG	**0,024**	**0,010**	0,045	0,033	0,054	0,036	**0,018**	0,034	0,040	

BEN= Benin, BURK= Burkina Faso, CAM= Cameroon, CIV= Côte d'Ivoire, GAB= Gabon, ML= Mali, NG= Niger, RCA= Central African Republic, SEN= Senegal, TG= Togo

Tableau 4: OCA index for ECOWAS Countries, 1990-2003

	BEN	BURK	CIV	GHA	ML	NG	NGR	SEN	TG
BEN									
BURK	0.020								
CIV	0.036	0.000							
GHA	**0.029**	**0.028**	**0,015**						
ML	0.029	0.023	0,009	0,035					
NG	0.029	0.028	0,027	0,032	0,037				
NGR	0.045	0,040	0,044	0,033	0,060	0,053			
SEN	0.031	0,037	0,022	0,043	0,008	0,035	0,051		
TG	0.024	0,010	0,033	**0,017**	0,036	0,018	0,059	0,040	

BEN= Benin, BURK= Burkina Faso, CIV= Côte d'ivoire, GHA= Ghana, ML= Mali, NG = Niger, NGR= Nigeria, SEN= Senegal, TG= Togo

Tableau 5: OCA index of SADC Countries, 1990-2003

	AFS	MAL	TANZ	ZAM	ZIM
AFS					
MAL	0,066				
TANZ	0,057	0,040			
ZAM	0,047	0,039	0,049		
ZIM	0,032	**0,014**	0,040	**0,012**	

AFS= Afrique du Sud, MAL= Malawi, TANZ= Tanzania, ZAM= Zambia, ZIM = Zimbabwe

Tableau 6: OCA index of COMESA Countries, 1990-2003

	BURU	KEN	MAL	OUG	RWA	TANZ	ZAM	ZIM
BURU								
KEN	0,034							
MAL	0,042	0,045						
OUG	0,040	**0,014**	0,036					
RWA	0,083	0,073	0,076	0,050				
TANZ	0,034	**0,018**	0,040	**0,030**	0,068			
ZAM	0,045	0,057	0,039	0,062	0,095	0,049		
ZIM	0,042	0,032	**0,014**	0,043	0,097	0,040	**0,012**	

BURU= Burundi, KEN= Kenya, MAL= Malawi, OUG = Uganda, RWA= Rwanda, TANZ= Tanzania, ZAM= Zambia, ZIM = Zimbabwe