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Is there a stochastic convergence process in the West African economic and monetary union in presence of multiple structural breaks from 1960 to 2010?

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Abstract

Our study analyses stochastic convergence of relative real GDP per capita in the West African Economic and Monetary Union (WAEMU) in the period 1960 to 2010. It highlights the importance of considering structural breaks and cross-section dependence in the panel unit root tests. Using the panel stationarity test proposed by Carrion-I-Silvestre, Barrio-Castro and Lopez-Bazo (2005), we show that there was stochastic convergence in the WAEMU, by allowing for multiple level and slope shifts in the trend and for a general form of cross-sectional dependence. In other words, this result assumes that the effects of structural shocks occurring in the WAEMU zone disappeared over time and the series representing the logarithm of relative GDP per capita reverted towards their respective equilibriums. So, it encourages the objectives of WAEMU enlargement to other countries of West Africa as far as all countries could benefit from this process according to the predictions of the theory of endogeneity of optimum currency area.

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1. INTRODUCTION

The West African Economic and Monetary Union (WEAMU) currently includes eight countries: Benin, Burkina Faso, Côte d'Ivoire, Guinea-Bissau, Mali, Niger, Senegal and Togo. Its progress to becoming an economic and monetary union has involved several stages. In May 1962, following their political independence, six former French colonies founded the West African Monetary Union (WAMU), which was joined by Togo in 1963. At that time, the treaty measures, which were ratified in 1973, concerned only rules for monetary emission, centralization of exchange reserves, freedom of transfers and free circulation of the "CFA Franc" (the currency of the zone) inside the union. This arrangement was to evolve, developing from a simple monetary union to the WAEMU in January 1994, in parallel with devaluation of the CFA franc. The WAEMU treaty includes four main themes: a harmonized legal and statutory framework, creation of a common market, multilateral surveillance of macroeconomic policies, and coordination of the national sectoral policies in the main fields of economic activity (Information Note 127, Bank of France). In January 1997, Guinea-Bissau joined the WAEMU.

The WAEMU rules, and the fact that the WAEMU belongs to the Franc Zone (FZ), prompted several studies. Some researches have focused on the FZ as an optimum currency area. Studies by Benassy-Quéré and Coupet (2005), and Tsangarides and Qureshi (2009), using hierarchical cluster analysis, conclude that the FZ is not an optimum currency area, but could be subdivided into small groups of homogeneous countries. Using a structural vector autoregressive method, Zhao and Kim (2009, p. 1877) concluded that domestic outputs of the FZ countries are strongly influenced by country-specific shocks…are structurally different from each other and thus are more likely to be subjected to asymmetric shocks…and do not appear to form an optimum currency area.

Concerning economic convergence, the studies experienced difficulties in showing it in the FZ, though it resurfaced with the findings of the endogenous growth model in the nineties. There are three concepts of convergence. First, Barro and Sala-i-Martin (1992) introduced the concepts of sigma (σ) and beta (β) convergence. σ-convergence refers to the process of narrowing in the dispersion of an indicator (GDP per capita) over time. β-convergence refers to the inverse relation between the starting position of a variable and its subsequent growth. The third concept, stochastic convergence, was introduced by Carlino and Mills (1993). This means that shocks to relative per capita income are temporary, thus leading the series to revert towards their respective equilibria. Some of these concepts have been analysed for the WAEMU, and σ-convergence has predominated along with a preference for nominal convergence[1].

Five years after the WAEMU convergence, stability, growth and solidarity treaty was signed, Bamba (2004) analysed the convergence process for the period 1980-2001. He applied the Kalman filter to the treaty criteria for each country relative to the criteria of Côte d'Ivoire (the most successful country in the zone), and found that the pact had accelerated the alignment of some countries with Côte d'Ivoire's inflation rate performance, although there

[1]The concepts of nominal and real convergence emerged in the context of European Union (EU). Nominal convergence refers to convergence among the 5 Maastricht criteria (1992) namely inflation rate, long run interest rate, budget deficit, public debt and nominal exchange rate, while real convergence refers to convergence in standard of living, productivity and economic structures.

was divergence in relation to budgetary criteria. Tanimoune and Plane (2005) analysed the σ-convergence of budget deficit in the zone and found a σ-convergence for the primary budget balance, although not enough to meet the zone's objectives.

At the level of the FZ, N'diaye (2007) analysed nominal and real convergence in the period 1980-2000, using recursive least squares. He notes that all the countries improved convergence in debt ratio, inflation rate and, to a lesser extent, budget deficit, especially after 1994, the year that the CFA franc was devalued. Owundi (2009) also analysed the convergence process at FZ level, but applying the Wilcoxon test and focusing on the impact of CFA franc devaluation. He shows that this event did not effectively impact on the convergence process. He explains that this was due to the lack of real convergence, great instability due to real and monetary shocks, and weak multilateral surveillance. More recently, Joubert et al. (2013) studied the convergence process for 46 African countries over the period 1985-2005 in terms of σ-convergence and β-convergence. They apply the methodology proposed by Evans and Karras (1996), and use generalized method of moments and the least square dummy variable corrector for the estimations. Their results indicate that there is no income convergence for any of the 46 countries, which they argue is due to the heterogeneity of these countries. However, they identify four convergence clubs, namely the countries of Economic Community of West African Countries (ECOWAS), WAEMU, the Monetary Community of Central Africa (MCCA) and the Southern African Development Community (SADC). Thus, most studies on the FZ focus on nominal and σ-convergence and there is no strong evidence of either σ-convergence or β-convergence. However, there are several lessons that can be learned from these studies, and especially that by Zhao and Kim (2009). They show that the FZ and, therefore, the WAEMU countries, are structurally different from one another, are strongly influenced by country-specific shocks, and are more likely to suffer asymmetric shocks. Also, none of the studies above-mentioned take account of shocks in their analyses, despite it being common knowledge that some shocks, depending on their magnitude, introduce structural breaks in time series.

Given that Perron (1989) shows that neglecting structural breaks could lead to erroneous results from the analysis of time series, the present study takes account of structural breaks in the analysis of economic convergence in the WAEMU. This is feasible since Carrion-I-Silvestre, Barrio-Castro and Lopez-Bazo (hereafter CBL) (2005) have developed a panel stationarity test that takes account of multiple structural breaks. The procedure is based on the panel data version of the Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) univariate test developed by Hadri (2000). Also, this test does not impose either equal numbers of breaks per country or the same structural breaks for all countries. This is particularly useful in the case of the WAEMU countries, as shown above. Hadri's structure of the test ensures that there is a strong evidence against the null of trend stationarity in order to conclude in favour of panel non-stationarity. Finally, this test includes controls for general forms of cross-sectional correlations and finite-sample bias by approximating the empirical distribution of the panel stationarity test through bootstrap methods. CBL (2005) explains that, in reality, the assumption underlying Hadri's (2000) panel test is rare since countries are seldom cross-section independent in the sense that shocks transcend national borders in a globalized economy and especially in an economic and monetary union. In this article, we have chosen to exploit all the opportunities provided by the CBL (2005) test in order to analyse the stochastic convergence between WAEMU members. Section 2 describes the data and the procedures of estimation and test. Section 3 presents the results of the estimation. Section 4 discusses the main result and Section 5 outlines our conclusions.

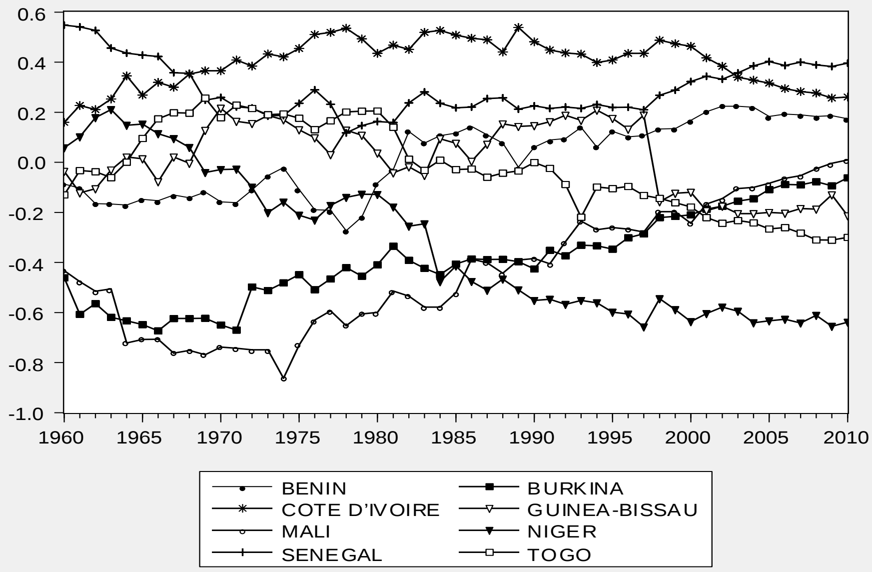
2. DATA AND ESTIMATION PROCEDURE

Before presenting the panel stationarity test, we briefly describe our data source, method of calculation and evolution of the variable of interest during the period of analysis.

To test stochastic convergence in the WAEMU, we use data from the Penn World Table 7.1, which contains observations on Benin, Burkina Faso, Côte d'Ivoire, Guinea-Bissau, Mali, Niger, Senegal and Togo from 1960[2] to 2010. For each country, we extracted real GDP per capita represented in the database by "purchasing power parity converted gross domestic product per capita in terms of Chain Series, at 2005 constant prices". Following Carlino and Mills (1993), we need to compute the logarithm of the ratio of country-specific real GDP per capita to the average real GDP per capita of our sample of eight countries, as follows: $LRGDP_{it} = Ln(GDP_{it}/\overline{GDP_t})$, where GDP_{it} denotes the real GDP per capita of country i at time t and $\overline{GDP_t}$ denotes the mean of the eight countries' real GDP per capita at period t.

Before presenting the CBL (2005) panel stationarity test, we need to conduct graphical analysis of the data. Figure 1 shows the global tendency towards convergence in the evolution of relative real GDP per capita for all countries except Niger, where the curve diverges. From the standard deviation shown in Figure 2, we can observe that there is a σ-convergence of relative real GDP per capita in the WAEMU. Therefore, we can proceed to analyse convergence in the WAEMU in terms of stochastic convergence.

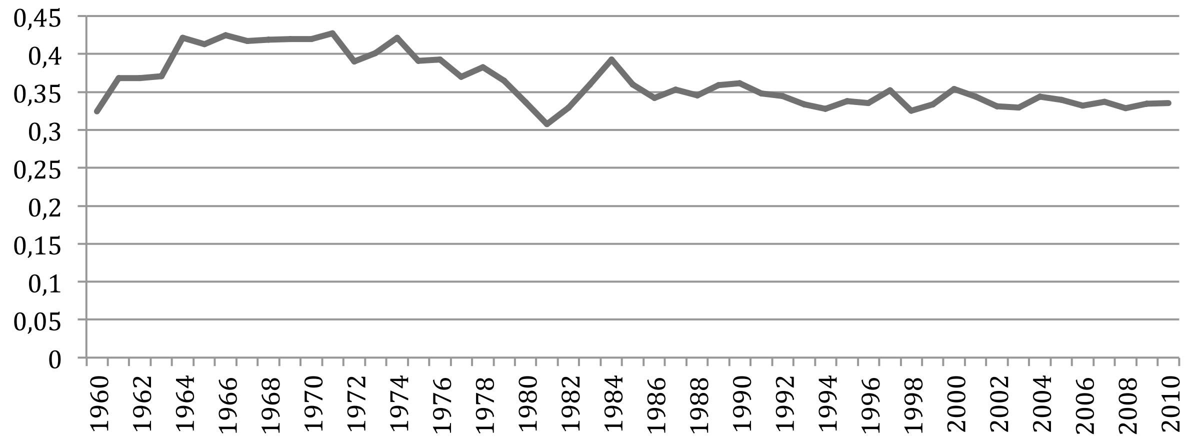
Figure 1: Relative real GDP per capitat evolution of WAEMU's countries from 1960 to 2010



Source: Author's calculation based on data from Penn World Table 7.1.

[2] 1960 was the year that the former French colonies of Benin, Burkina Faso, Côte d'Ivoire, Mali, Niger and Senegal gained political independence. Guinea-Bissau achieved political independence in 1974.

Figure 2: The evolution of the relative real GDP per capita standard deviation in the WAEMU (1960-2010)



Source: Author's calculation based on data from Penn World Table 7.1.

To carry out the CBL (2005) panel stationarity test, we have to consider $LRGDP_{it}$ as a stochastic process, which, under the null hypothesis of stationarity, is characterized by the following data-generating process:

$$LRGDP_{it} = \alpha_i + \sum_{k=1}^{m_i} \gamma_{i,k} DU_{i,k,t} + \beta_i t + \sum_{k=1}^{m_i} \theta_{i,k} DT^*_{i,k,t} + \varepsilon_{i,t} \quad (1)$$

where α_i represents country-specific characteristics that do not vary over time, and $\beta_i t$ represents country-specific linear time trends. The dummy variables for changes in the slope and level are given by $DT^*_{i,k,t}$ and $DU_{i,k,t}$, respectively, such that $DT^*_{i,k,t} = t - T^i_{b,k}$ for $t > T^i_{b,k}$ and 0 otherwise, and $DU_{i,k,t} = 1$ for $t > T^i_{b,k}$ and 0 otherwise; with $T^i_{b,k}$ denoting the kth break location for the ith individual for $k = 1, \ldots, m_i \; with \; m_i \geq 1$.

Thus, after applying the CBL (2005) panel stationarity test (details of procedure in appendix 1), if we find a unit root in the logarithm of the relative real GDP per capita, in other words, if we reject the null of trend stationarity, we can conclude that there is real GDP per capita divergence in the WAEMU. However, if we find stationarity in the logarithm of relative real GDP per capita we can deduce that there is stochastic convergence of real GDP per capita in that zone. Thus, this deduction implies that shocks occurring in the WAEMU are temporary and vanish with time.

3. EMPIRICAL RESULTS

As already noted, if the panel stationary test does not take account of structural breaks, this could lead to erroneous conclusions. Also, Romero-Avila (2009), based on Maddala and Wu (1999), refers to size distortions in panel tests due to the hypothesis of cross-sectional independence. We therefore also compute the empirical distribution of the tests obtained using bootstrap methods with 20,000 replications, allowing for general forms of cross-sectional dependence. Thereafter, the statistic $Z(\hat{\lambda})$ must be compared with the critical values in an upper-tailed standard normal distribution.

In order to justify this practice, Table 1 presents the Hadri (2000) panel test without structural breaks, and its bootstrap critical values assuming cross-section dependence between countries as a more realistic hypothesis. We find that the KPSS test cannot reject the null of trend stationarity only, for Benin and Burkina Faso. At the 10% level, the KPSS test rejects the null of trend stationarity for Guinea-Bissau. At the 5% level, it rejects the null of trend stationarity for Côte d'Ivoire, Mali, Niger, Senegal and Togo.

Table 1: Panel KPSS test without structural breaks

A- Country specific tests			
	KPSS		
BENIN	0.085		
BURKINA FASO	0.111		
COTE D'IVOIRE	0.192**		
GUINEA-BISSAU	0.142*		
MALI	0.154**		
NIGER	0.149**		
SENEGAL	0.180**		
TOGO	0.150**		
B- Panel KPSS test without breaks			
HOMOGENEITY OF LONG-RUN VARIANCE			
	BOOTSTRAP CRITICAL VALUES ASSUMING CROSS-SECTION DEPENDENCE		
	10%	5%	1%
$Z(\hat{\lambda})$ = 6.097	4.712	5.171	5.983
HETEROGENEITY OF LONG-RUN VARIANCE			
	BOOTSTRAP CRITICAL VALUES ASSUMING CROSS-SECTION DEPENDENCE		
	10%	5%	1%
$Z(\hat{\lambda})$ = 5.322	3.893	4.278	5.940

Notes: According to Sephton (1995, p. 259), the KPSS test finite-sample critical values for the specification with trend for the 1%, 5% and 10% levels are respectively 0.213, 0.149 and 0.121 for T=50.
The symbols ***, ** and * imply rejection of the null hypothesis at the 1%, 5% and 10% levels respectively. Bootstrap critical values are obtained through 20,000 replications.

Turning to the Hadri panel stationary test (2000), the null of trend stationary can be rejected at the 1% conventional level if cross-section independence is considered for either homogeneity or heterogeneity of long run-variance. If we relax the hypothesis of cross-section independence, we are still able to reject the null of trend stationary at the 1% level in the case of homogeneity of long run variance. However, in the case of heterogeneity of long run variance, we can only reject the null of trend stationary at the 5% level. In line with Romero-Avila (2009), when we compare the Hadri test with the bootstrap critical values, we see a dramatic shift in critical values to the right of the upper tail of the standard normal distribution. Given that the WAEMU countries are heterogeneous in terms of specialization, exposure and vulnerability to shocks, we prefer these critical values. However, this result should be interpreted with caution; Perron (1989) shows that neglecting structural breaks when analysing time series could lead to erroneous results. The WAEMU countries generally have suffered numerous heterogeneous shocks between 1960s and 2010. These include several coups d'état and the two oil crises in the 1970s, the debt crisis and ensuing structural adjustment programmes in the 1980s, and the FCFA devaluation in the 1990s. Depending on the country concerned, some shocks have been transitory while others have had a dramatic effect on the functioning and evolution of national economies with consequences for the convergence process. For this reason, future analyses of stochastic convergence should control for structural breaks. So, we use the procedure in Bai and Perron (1998) to identify endogenously break dates. Since our variable of interest is relative real GDP per capita, the break dates identified by this procedure will be related to the WAEMU and not to each specific country in the zone.

Table 2: Panel KPSS test with Structural Breaks

A- Country specific tests

	Break dates				KPSS	Finite sample critical values		
	1	2	3	4				
BENIN	1972 [1969,1973]	1979 [1978,1980]	1986 [1985,1991]	2000 [1999,2001]	0.028**	10% 0.023	5% 0.025	1% 0.030
BURKINA FASO	1971 [1970,1973]	1997 [1996,2001]			0.046*	10% 0.042	5% 0.049	1% 0.066
COTE D'IVOIRE	1975 [1974,1976]	1982 [1981,1983]	1997 [1995,1998]		0.032**	10% 0.028	5% 0.031	1% 0.038
GUINEA-BISSAU	1969 [1968,1970]	1983 [1982,1984]	1997 [1996,1998]		0.029**	10% 0.026	5% 0.028	1% 0.034
MALI	1967 [1966,1969]	1974 [1973,1978]			0.031	10% 0.067	5% 0.081	1% 0.115
NIGER	1966 [1965,1968]	1976 [1975,1978]	1983 [1982,1984]	1997 [1996,2002]	0.022	10% 0.023	5% 0.025	1% 0.031
SENEGAL	1974 [1973,1975]	1981 [1980,1985]	1997 [1996,1998]		0.029*	10% 0.028	5% 0.031	1% 0.038
TOGO	1969 [1968,1970]	1981 [1980,1982]			0.044	10% 0.048	5% 0.057	1% 0.079

B- Panel KPSS test with breaks

HOMOGENEITY OF LONG-RUN VARIANCE			
	BOOTSTRAP CRITICAL VALUES ASSUMING CROSS-SECTION DEPENDANCE		
	10%	5%	1%
$Z(\hat{\lambda})$ = 3.188	8.149	9.500	12.352
HETEROGENEITY OF LONG-RUN VARIANCE			
	BOOTSTRAP CRITICAL VALUES ASSUMING CROSS-SECTION DEPENDANCE		
	10%	5%	1%
$Z(\hat{\lambda})$ = 3.019	6.559	7.202	8.467

Notes: The symbols ***, ** and * imply rejection of the null hypothesis at the respective 1%, 5% and 10% levels. The finite sample critical values are obtained through Monte Carlo simulation with 20,000 replications. The bootstrap critical values are obtained through 20,000 replications.

Table 2 presents the break dates and the associated 90% confidence intervals, and also the new results of the KPSS and CBL (2005) panel stationarity tests taking account of structural breaks in the series. Table 2 also reports the finite sample critical values for the KPSS test obtained from the Monte Carlo simulation and bootstrap critical values for the Hadri panel stationarity test, both in turn obtained from 20,000 replications. The introduction in the estimation of break date variables (constant+trend) involves that the asymptotic critical values of Sephton (1995) are no longer reliable.
The KPSS test results show that we can reject the null of trend stationarity for Benin, Côte d'Ivoire and Guinea-Bissau at the 5% level and, to a lesser extent, for Burkina Faso and Senegal at the 10% level. However, we can no longer reject the null of trend stationarity for Mali, Niger and Togo. Turning to the panel stationary test, we are still able to reject the null of trend stationarity if we assume cross-section independence. Since this is difficult to imagine, we favour the bootstrap critical values under cross-section dependence. If we do this, we are no longer able to reject the null of trend stationarity for either homogeneity or heterogeneity of long-run variance at the conventional significance level.
Taking account of structural breaks and cross-section dependence allow us to conclude that there is stochastic convergence in the WAEMU. In other words, the frequent breaks in corresponding decades makes it likely that the two oil crises, the debt crisis of the eighties and the structural adjustment programmes among other factors disturbed the process of convergence in the WAEMU. Added to the results in CBL (2005) and Romero-Avila (2009), our results provide further justification for considering structural breaks when analysing the convergence process, especially in the case of developing countries which are subject to frequent shocks of various kinds (political, coups d'état, price instability, climate, restructuring, etc).

4. DISCUSSION

Our study follows the logic and provides similar results to work on stochastic convergence by Carlino and Mills (1993, 1996) for US regions, Romero-Avila (2009) for the OECD countries, Evans and Kim (2011) for 13 Asian countries, and Cuñado and Perez De Gracia (2006) for 43 African countries. All these studies show evidence of stochastic convergence after taking account of structural breaks and, in some cases, the possibility that countries might be cross-correlated.
The evidence of stochastic convergence involves that the effects of structural shocks occurring in the WAEMU zone disappeared over time, and the series representing the log of relative GDP per capita reverted towards the respective equilibria. Our results might suggest that stochastic convergence might be due to the existence of an Optimum Currency Area (OCA). However, the studies of Benassy-Quéré and Coupet (2005), Tsangarides and Qureshi (2008) and Zhao and Kim (2009) make it difficult to claim that the WAEMU is an OCA. This then raises another question. Is the WAEMU case validation of the Krugman specialization hypothesis? Some authors (Krugman 1993, and Bertola 1993) have suggested that as countries become more integrated they will produce goods and services in which they have comparative advantage and be increasingly less likely to form an OCA. Although this hypothesis has been confirmed in the cases of the USA (Krugman 1993) and the European Union (Eichengreen 1996), it does not hold for the WAEMU for at least two reasons. First,

specialization, structure and system of production are the legacy of the colonial period and have changed little since political independence. Second, the degree of integration and volume of trade between WAEMU members is not well developed.

However, our result might militate for the hypothesis of endogeneity of OCA. Despite the heterogeneity of the WAEMU countries, the diversity of the shocks that occurred in each country and the fact that WAEMU is not an OCA, our result shows that there is no divergence of relative income and, even better, there is global tendency of narrowing of the gaps (Figure 2). The hypothesis of endogeneity of the OCA[3] suggests that membership in an economic and/or currency area increases credibility, raises trade barriers, facilitates foreign direct investment, avoids future competitive devaluation and enforces collaboration among members. Some of these features have been observed for the WAEMU zone, for example in work by Bamba (2004) and Tanimoune and Plane (2005) among others, in terms of nominal convergence. Based on these advantages, one can expect more trade, better synchronization of business cycles, and integration of economic, financial and political activities among members in the future (Frankel and Rose 1997). According to Frankel and Wei (1998), all these features have contributed to increasing the trade in European Union. Similarly, Fielding and Shields (2005, p. 700) provide strong evidence that Franc Zone (of which WAEMU is an integral part) membership has promoted higher trade volumes in the past than could otherwise have been expected. Not only there has been a positive single-currency effect, but also, trade has been higher between Franc Zone members in different monetary unions between which there is a fixed exchange rate. This bodes well for the hoped-for enlargement of the WAEMU to other West African countries promoted by the conference of heads of state and governments of the Economic Community of West African Countries (ECOWAS) held in 1999.

However, stochastic convergence implies only that the log of relative GDP per capita does not diverge, not necessarily that there is a real convergence among WAEMU members. Future work should supplement stochastic convergence with a time series β-convergence analysis along the lines of Carlino and Mills (1993, 1996).

5. CONCLUSION

Following the papers by CBL (2005), Romero-Avila (2009) and other researchers, our study underlines the relevance of taking account of structural breaks when analysing the process of stochastic convergence. We exploited a relatively recent panel stationarity test with multiple structural breaks, developed by CBL (2005), to analyse the process of stochastic convergence in the WAEMU in the period 1960 to 2010. As well as allowing for different numbers of structural breaks at different dates for each country, this test overcomes the assumption of cross-sectional independence among countries, in the sense that it takes account of globalized and tied economies, especially in the WAEMU. This allowed us to show evidence of stochastic economic convergence in the WAEMU.

Our result supports the hypothesis of endogeneity of OCA. Indeed, despite the heterogeneity of the WAEMU countries, the diversity of shocks by country and the fact that WAEMU is not an OCA, our result shows that there is no divergence of relative income and, even better,

[3] Mongelli (2002) provides a good review of the literature on OCA .

there is global tendency towards a narrowing of the gaps. It provides encouragement for the enlargement of the WAEMU to other countries of West Africa as far as all countries could benefit from this process according to the predictions of the theory of endogeneity of OCA.

Appendix 1: CBL (2005) panel stationarity test procedure

From equation 1, CBL (2005) computes the panel stationarity test ($\eta\,(\widehat{\lambda})$) as the average of univariate KPSS tests as follows:

$$\eta(\hat{\lambda}) = N^{-1}\sum_{i=1}^{N}\left(\widehat{\omega}_i^{-2}T^{-2}\sum_{t=1}^{T}\hat{S}_{i,t}^2\right) \tag{2}$$

where $\widehat{\omega}_i^{-2}T^{-2}\sum_{t=1}^{T}\hat{S}_{i,t}^2 = \eta_i(\hat{\lambda}_i)$ is the univariate KPSS test for individual i and $\hat{S}_{i,t} = \sum_{j=1}^{t}\hat{\varepsilon}_{i,j}$ the partial sum of the estimated ordinary least squares residuals. $\widehat{\omega}_i^2$ stands for an autocorrelation and heteroskedasticity-consistent estimate of the long-run variance of the residuals, which is obtained, as in Kurozumi (2002), using the Bartlett Kernel with fixed bandwidth computed as follows:

$$\hat{l} = min\left\{1.1447\left[\frac{4\hat{a}^2T}{(1+\hat{a})^2(1-\hat{a})^2}\right]^{1/3}, 1.1447\left[\frac{4k^2T}{(1+k)^2(1-k)^2}\right]^{1/3}\right\} \tag{3}$$

where $\hat{a}$ is the autoregressive parameter estimated using the method proposed by Andrews (1991) and $k = 0.7$ is the preferred value according to Kurozumi's simulations.

According to Hadri (2000) and CBL (2005), it's possible to allow for either heterogeneity or homogeneity in the estimation of long-run variances across countries. To impose homogeneity, we have only to replace $\widehat{\omega}_i^2$ by $\widehat{\omega}^2 = N^{-1}\sum_{i=1}^{N}\widehat{\omega}_i^2$ in equation (2) that is the mean across the countries. We will compute the two kinds of CBL (2005) statistics for robustness check.

An important feature of this panel test is that it is dependent on the location of the breaks (λ_i) that is *a priori* unknown. In order to be as objective as possible, we determine these breaks endogenously by using the procedure of Bai and Perron (1998) for each country. The appropriate number of breaks is chosen using the Bayesian Information Criterion (BIC). After obtaining the dates of the breaks for every country, we have to compute the averages of individual means (ξ_i) and variances (ς_i^2) of each country's KPSS test $\left(\eta_i(\hat{\lambda}_i)\right)$. CBL (2005) demonstrated that:

$$\xi_i = A\sum_{k=1}^{m_i+1}\left(\lambda_{i,k} - \lambda_{i,k-1}\right)^2 \tag{4}$$

$$\varsigma_i^2 = B\sum_{k=1}^{m_i+1}\left(\lambda_{i,k} - \lambda_{i,k-1}\right)^4 \tag{5}$$

where $\lambda_i = \left(\lambda_{i,1}, \dots, \lambda_{i,m_i}\right)' = \left(T_{b,1}^i/T, \dots, T_{b,m_i}^i/T\right)$ indicates the relative positions of the dates of the breaks on the entire time period T. In our case, that is the model with structural breaks, $A = {}^{1}/_{15}$ and $B = {}^{11}/_{6300}$.

Once all the previous parameters have been derived, the CBL (2005) panel statistic can be computed as follows:

$$Z(\hat{\lambda}) = \frac{\sqrt{N}[\eta(\hat{\lambda}) - \bar{\xi}]}{\bar{\varsigma}} \xrightarrow{d} N(0,1) \tag{6}$$

where $\overset{d}{\rightarrow}$ denotes weak convergence of the distribution. The limiting distribution of the statistic is derived using sequential asymptotic theory, in which $T \rightarrow \infty$ is followed by $N \rightarrow \infty$.

As CBL (2005) notes, the $Z(\hat{\lambda})$ statistic assumes cross-sectional independence, which is unlikely to hold in a globalized economy where shocks extend beyond the borders of national economies, much less in the WAEMU where the countries are related by a single currency, a single exchange rate, pacts, operational rules, "solidarity", etc. Therefore, CBL suggests computing a bootstrap distribution following Maddala and Wu (1999), to allow for general forms of cross-sectional dependence. Also, for the KPSS test, we compute finite-sample critical values through Monte Carlo simulations for the test with breaks.

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