

## Asymmetry in Exchange Rate Pass-Through to Consumer Prices: New Perspective from Sub-Saharan African Countries

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**Abstract:** This paper examines the asymmetrical relationship between exchange rate and consumer prices in 40 Sub-Saharan African (SSA) countries from 1990q1 to 2017q4. The exchange rate pass-through (ERPT) to consumer prices is estimated for each country by using the nonlinear autoregressive distributed lags (NARDL) framework and dynamic panel estimators robust to cross-sectionally correlated errors. Firstly, our findings suggest an asymmetrical ERPT in the SSA region during the short-term, whereas there are mixed results across sub-regions in the long-term. Next, we find incomplete and significant ERPT to consumer prices in the entire SSA region which is higher during the depreciation of the local currency than after appreciations. Third, we find nonlinear ERPT with respect to the size of the exchange rate. The pass-through is higher during large exchange rate changes than after small changes. Finally, we find that the pass-through is greater in the countries with fixed exchange rate regime (CFA franc zone) having low inflationary environment than in the other SSA countries with flexible exchange rate regime and high inflation levels. As a result, policymakers should take into account these asymmetries and non-linearities to improve the credibility of monetary policy, strengthen trade liberalization and establish competitive market structures in the Sub-Saharan region.

**Keywords:** Asymmetry; Exchange rate pass-through; NARDL; Inflation; Sub-Saharan Africa

**JEL classification:** C13, E31, F31

## 1. Introduction

The interest in the exchange rate pass-through analysis is justified by the need to understand how economic cycles, trade imbalances, especially exchange rate changes affect domestic prices and monetary policy. Indeed, exchange rate pass-through (ERPT, hereafter) denotes the degree to which exchange rate changes are transferred into prices in a particular country. Thus, several studies analyzed the ERPT to import and consumer prices, initially in developed countries, suggesting its fall since 1990s. Taylor (2000) found that ERPT has declined under low inflationary environment in the US during the 1990s and this hypothesis has been largely validated by other studies in advanced nations (Campa and Goldberg 2002; Choudhri et al. 2002; Campa and Goldberg 2005; Takhtamanova 2010). Most of these studies ignored the likely asymmetrical ERPT to prices (inflation) underlined in the theoretical models of pricing to market where foreign exporters adjust the prices in the importing country in response to the size and direction of exchange rate movements. Accordingly, recent studies consider nonlinearities and asymmetry in their investigation of the relationship between exchange rate and domestic prices in the developed and emerging economies (Brun-Aguerre et al. 2012; Choudhri and Hakura 2015; Yanamandra 2015; Brun-Aguerre et al. 2016; Baharumshah et al. 2017, among others). In fact, these studies revealed an asymmetrical and non-linear ERPT to import prices as well as a complete and high pass-through during exchange rate depreciations than appreciations in the long-term.

The need to examine the relationship between exchange rate and prices is an important step for the Sub-Saharan African countries (SSA) to secure their economy against structural shocks during the global trade. By the early 2000s, several SSA countries have benefited from stable and low inflation level with sustained growth. However, the policy framework presents some weaknesses because of the limited role of the exchange rate to be used as a nominal anchor. One of the common features with the SSA countries that distinguish them from other regions is the lack of credibility of the monetary policy. At earlier stages of credibility, the trade-off between output and inflation is more severe. Most SSA countries focus on inflation targeting policy to the detrimental of the anchoring role of the exchange rate. Most of the SSA countries, i.e. the CFA franc region (WAEMU and CEMAC) has pegged their currency to the euro, resulting to low inflation level in this region compared with the other SSA countries.

Concerning Sub-Saharan African countries (SSA), the literature on ERPT is limited and based on some specific countries rather than the whole SSA region (Bhundia 2002; Mwase 2006; Karoro et al. 2009; Maka 2013; Jooste and Jhaveri 2014; Bada et al. 2016). However, Akofio-Sowah (2009) examined the relationship between ERPT and monetary regime only for 15 SSA countries during the period 1980-2005. He unveiled that the pass-through was lower in the countries under low inflationary environment. The International Monetary Fund's working paper of Razafimahefa (2012) extended the ERPT analysis to 34 SSA countries on quarterly time series from 1980 to 2005 using a VAR framework. The author suggested a declining pass-through in the 1990s due to macroeconomic reforms. Most of these studies are country levels and neglect the asymmetry and nonlinearities' assumption between exchange rate changes and domestic prices in the SSA countries, as well as cross-sectional dependence across countries which may lead to biased results.

Accordingly, our study examines the asymmetry and nonlinearities of ERPT to consumer prices from 1990q1 to 2017q4 for 40 SSA countries split in two groups: the CFA franc zone having fixed exchange rate regime (Waemu and Cemac, 14 countries) and the other SSA countries with flexible exchange rate regime (26 countries). Then, we also consider cross-sectional dependence between countries which may arise from unobserved common factors. Especially, we conduct tests on the following hypotheses: Is there a symmetrical ERPT to consumer prices during depreciations and appreciations? Is there a non-significant ERPT in long-term? Is there evidence of a complete ERPT in the SSA countries? Does the size of the exchange rate matter in the likely asymmetrical ERPT?

First, we estimate the ERPT for each country by employing the NARDL framework of Shin et al. (2014) and the general to specific' approach with maximum lag length 4, dropping all insignificant

variables in the regression. The results reject the hypothesis of a symmetrical ERPT for most of the SSA countries (30 cases in the long-term and 24 cases out of 40 in the short-term). We also find an incomplete ERPT except for 6 cases where the evidences of a complete ERPT are only found for depreciations in Angola and Kenya and one case for appreciation in Liberia. Then, we find an asymmetrical and complete ERPT in Ghana and Lesotho over the long-term and only one case in the short-term for depreciation in Mozambique. In addition, we unveil many cases of significant ERPT over the short and long-term. Moreover, the dynamic multipliers also confirm the asymmetrical pattern of exchange rate to local prices in most of the cases. Second, the cross-sectional dependence tests confirm the existence of cross-sectionally correlated residuals between the panel units. Third, we employ the Feasible Generalized Least Squares (FGLS) estimator of Parks (1967) and the Pooled OLS regression with Driscoll and Kraay (1998)'s standard errors which are consistent to heteroscedasticity and cross-sectionally correlated residuals. These panel estimators validate both the short and long-term asymmetrical ERPT for CFA franc zone and only the short-term asymmetrical ERPT for the other SSA countries as well as the entire SSA region. Besides, our findings of an incomplete and non-Zero ERPT are robust across the SSA countries under the cross-sectional dependence analysis where depreciations are strongly passed through consumer prices than do appreciations in the short and long-term. The ERPT is higher in the CFA franc zone having lower inflationary environment and price volatility than the other SSA countries which contrasts the Taylor (2000)'s hypothesis. Furthermore, the pass-through coefficients become lower under the cross-sectional dependence analysis and higher in the long-term than in the short-term. Finally, we find an asymmetrical ERPT with regard to the size of the exchange rate. The pass-through is higher after large exchange rate changes than small changes. Especially, the ERPT during large depreciations of the local currency is greater than that for large appreciations, whereas the ERPT for small appreciations is higher than that for small depreciations.

Hence, our contribution to the ERPT's literature in the SSA region is threefold: we extend the analysis to 40 SSA countries using both per country and dynamic panel analysis, allowing for asymmetry and nonlinearities; second, we consider the cross-sectional dependence analysis between countries in the estimation of ERPT. Finally, we examine the pass-through with regard to the size of the exchange rate. Our findings reveal the lack of credibility of the monetary policy in the SSA region and the evidence of speculative behavior from foreign producers. This raises concerns about the deterioration of the consumer welfare in the destination market following the response of local prices and thereby may hinder the monetary policy of inflation targeting and export competitiveness. The asymmetrical ERPT also reflects downward prices rigidities and weak market competition in many SSA countries. Therefore, the SSA countries may benefit from trade liberalization and competitive market structures.

The remainder of this paper is structured as follows: section 2 presents the literature on ERPT; section 3 describes the data and the methodology used in this study; section 4 presents the findings and discussions while section 5 exposes the conclusion and policy implications.

## 2. Literature review

### 2.1. Theoretical review

The asymmetrical behavior of exchange rate changes in prices is often underlined in the microeconomic context of pricing to market theory stating that foreign firms are prone to adjust their markups in the importing country in response to exchange rate changes (Dornbusch 1985; Krugman 1986). Moreover, this likely asymmetrical pattern of exchange rate is largely explained in the market share model (Marston 1990) where foreign exporters tend to pass-through the appreciation of the importer's currency in order to enhance their market share while absorbing the depreciation to maintain their profits. Thus, the exchange rate pass-through (ERPT) is higher during appreciation of the importer's currency than depreciation, similar to the technology switching model (see Ware and Winter 1988). Conversely, the capacity constraints' model of Knetter (1994) posits that foreign firms are inclined to pass-through depreciation of the importer's currency and absorb appreciation

because they operate at full capacity and may not be able to contain huge demand when the importer's currency appreciates. Finally, Pollard and Coughlin (2004) demonstrate that asymmetry may arise from the pricing strategy of a foreign firm in response to exchange rate's size. Thus, under the hypothesis that foreign exporters set the invoice price in their own currency, they are less incentive to adjust the price following small change in exchange rate so that the price faced by the importer fully reflects exchange rate changes. This strategy is termed as *producer currency pricing* (PCP) where there is a complete ERPT. On the other hand, prices are not sensitive to small changes in the exchange rate when exporters set the invoice price in the importer's currency, which is consistent with the *local currency pricing* strategy (LCP). In this case the ERPT is zero and may increase if prices adjust to large exchange rate changes.

## 2.2. Empirical review

Most of the studies on exchange rate changes and local prices' relationship initially suggested a symmetrical and declining exchange rate pass-through (ERPT) to prices over the years, especially in the developed countries (Taylor 2000; Olivei 2002; Campa and Goldberg 2005; among others). For instance, Otani et al. (2003) found a lower ERPT into the import prices for Japanese industries in the 1990s using monthly data from 1978 to 2002 on both overall and disaggregate import prices. Likewise, Takhtamanova (2010) validated the Taylor (2000)'s hypothesis of a declining ERPT under a low inflationary regime during the 1990s in 14 developed nations. This hypothesis has been supported by several other studies (Choudhri et al. 2005; Frankel et al. 2011; Ozkan and Erden 2015). Besides, several empirical studies concluded that the pass-through to prices was incomplete and smaller, lying between 0 and 1 in the developed nations than in the developing countries (Goldberg and Knetter 1996; Berner 2010; Bussière et al. 2014, among others). Berner (2010) studied the exchange rate pass-through (ERPT) to import unit values of Germany using monthly data from 1988 to 2008. He found an incomplete and nonlinear ERPT which was higher during depreciations of the Euro than appreciations, differing across trading partners.

The investigation of exchange rate and prices' relationship has moved forward by allowing for an asymmetrical and nonlinear ERPT to prices levels in the developed and emerging countries (Delatte and López-Villavicencio 2012; Yanamandra 2015; Brun-Aguerre et al. 2016; Baharumshah et al. 2017; Kassi et al. 2018, among others). Brun-Aguerre et al (2016) investigated the ERPT into import prices for an unbalanced panel data of 14 Emerging Markets and 19 Developed Markets from 1980q1 to 2010q4. Most of these aforementioned studies employed a nonlinear autoregressive distributed lag (NARDL) framework of Shin et al. (2014) and revealed an asymmetrical ERPT in which exchange rate depreciations were passed through to prices more strongly than appreciations in the long-term. However, Utku Özmen and Akçelik (2017) utilized micro data to investigate the impact of oil prices and exchange rate on retail motor fuel prices in Turkey from January 1<sup>st</sup>, 2006 to February 14<sup>th</sup>, 2014. They unveiled an asymmetrical response of motor fuel prices which was intensified by exchange rate changes (oil price) in the case of positive (negative) cost shock. They also showed that the pass-through size was inversely associated to the level of positive cost shock, concluding that the market structure was the major reason of this asymmetry. Additionally, Kassi et al. (2018) found an asymmetrical ERPT in the developing and emerging Asian countries by using the NARDL framework on quarterly data from 1995q1 to 2016q4.

The research on ERPT in Sub-Saharan African countries has been scarce, largely dominated by country level studies. Bhundia (2002) analyzed the ERPT to consumer prices in South Africa and found a lower pass-through by using a vector autoregressive (VAR) framework on quarterly data from 1976q2 to 2000q3.

Mwase (2006) also unveiled a declining ERPT in Tanzania in the 1990s through a structural VAR model with a data set from 1990 to 2005. He argued that the lower pass-through was in part favored by the structural and macroeconomic reforms during the 1990s. Moreover, Akofio-Sowah (2009) investigated the relationship between exchange rate pass-through and the monetary regime in 12 Emerging countries and 15 Sub-Saharan African countries from 1980 to 2005. The author revealed

that ERPT was lower in countries having low inflation levels, especially in CFA franc zone, the common monetary area (CMA) than others. Another study of Frimpong and Adam (2010) examined the ERPT to Ghanaian consumer prices with a VAR model on a monthly data over 1990m1-2009m2 periods. They concluded a declining and incomplete ERPT into prices which was significant in the short-term. In the IMF's working papers, Razafimahefa (2012) gave an analysis covering 34 Sub-Saharan African (SSA) countries split into fixed regimes (23 countries) and flexible regimes (11 countries). The author analyzed ERPT and its determinants in the SSA countries on quarterly data from 1985 to 2008 where he also suggested an incomplete ERPT estimated at about 0.4 and higher during exchange rate depreciations than appreciations. Then, he affirmed that the ERPT degree has declined in the 1990s due to macroeconomic reforms, being lower in countries with higher income and more flexible exchange rate regimes. Maka (2013) investigated the asymmetrical ERPT to inflation in Ghana by using a structural VAR model on monthly data set from 1990m1 to 2011m12. Maka (2013) found that the pass-through was asymmetrical with depreciations having a significant and positive impact on consumer prices contrary to appreciations. In addition, he indicated a complete pass-through to non-food prices but incomplete for food prices. Jooste and Jhaveri (2014) examined the time-varying ERPT in South Africa, where they suggested a declining pass-through over time under low inflationary environment. They also found that the ERPT was high during periods of exchange rate volatility. The ERPT to prices has been also studied in Malawi (Jombo et al. 2014) and Nigeria (Bada et al. 2016) revealing a lower pass-through in these countries. Thus, a striking feature of the studies on ERPT in the SSA region is that most of them are country level studies and neglect the possibility of non-linearity and asymmetry in the relationship between exchange rate changes and domestic prices, as well as the cross-sectional dependence between countries. Hence, our study aims to fill this gap in the ERPT literature in the SSA region by addressing these issues.

### 3. Data and Methodology

#### 3.1. Data and model specification

This study examines the exchange rate pass-through (ERPT) to consumer prices index (CPI) on quarterly data from 1990:q1 to 2017:q4 by using databases from International Financial Statistics (IFS) and World Development Indicators (WDI). Thus, this paper utilizes an unbalanced panel data covering 40 Sub-Saharan African (SSA) countries separated into two main groups. The first group is the CFA franc zone (14 countries) with fixed exchange rate' regime, comprising the Central African Economic and Monetary Community (Cemac with 6 countries) and the West African Economic and Monetary Union (Waemu with 8 countries). The second group encompasses the remaining countries having flexible exchange rate regime (26 countries) and excluding the Cemac and Waemu sub-regions. Our sample is made up of heterogeneous data comprising different periods with the longest being ranging from 1990q1 to 2017q4 and the shortest from 2007q1 to 2017q4, which gives a sample size ranging from 44 to 112 observations. This is mainly due to data availability for some countries. However, one way to deal with this problem is to use a wide range of panel units and use appropriate econometric techniques to increase the reliability of our results.

Moreover, as a starting point we employ a modified specification of Delatte and López-Villavicencio (2012) and Brun-Aguerre et al. (2016). Especially, we formulate and adjust our empirical model following the framework of Mohsen Bahmani-Oskooee & Amirhossein Mohammadian (2017) in order to investigate the relationship between exchange rate and consumer price in Sub-Saharan Africa:

$$lcpi_{i,t} = \alpha_i + \Theta_i ler_{i,t} + \xi_i lmon_{i,t} + \kappa_i lgdp_{i,t} + \psi_i loil_{i,t} + \varepsilon_{i,t} \dots [1]$$

Where  $lcpi$ ,  $ler$ ,  $lmon$ ,  $lgdp$  and  $loil$  are the logarithmic transformations of consumer price index ( $cpi$ ), nominal exchange rate ( $er$ , the amount of local currency needed for 1 USD dollar), money supply ( $mon$ ), gross domestic product ( $gdp$ ) and price of crude oil ( $oil$ , a proxy for foreign price) respectively;  $\alpha_i$ ,  $\Theta_i$ ,  $\xi_i$ ,  $\kappa_i$  and  $\psi_i$  are the parameters for the country  $i$  and  $\varepsilon$ , the error term. We

use quarterly data from International Financial Statistics (IFS) for consumer price index, nominal exchange rate and crude oil price. However, we utilize annual data for the gross domestic product (GDP) and money supply (broad money, as % of GDP) from World Development Indicators (WDI) because data of these variables are not available on a quarterly basis for the whole sample. Then, we convert the annual data into the quarterly data by employing the low to high-frequency technique. In fact, the conversion is done by using the quadratic-match average option of the low to high-frequency method. This method applies an interpolation fitting a local quadratic polynomial such that the average of four adjacent quarters equals the data observed in the corresponding year. The subscripts  $i$  and  $t$  denote country and time representations respectively.

Hereafter, we follow the non-linear autoregressive distributed lag (NARDL) approach developed by Shin et al. (2014) to investigate whether there is long-term a cointegration and an asymmetrical relationship between the consumer prices index (inflation) and exchange rate in the SSA countries. Some advantages of this approach are its suitability for small sample size and its good performance in presence of variables which are not integrated in the same order (I(0) or I(1)). In addition, this framework has another advantage for testing short and long-terms nonlinearities in the relationship between variables through positive and negative partial sum decompositions of exogenous variables. However, the NARDL framework cannot be employed for integrated variables of order 2.

Especially, our NARDL model is a modified version of the autoregressive distributed lag (ARDL) following Campa and Goldberg 2005; Delatte and López-Villavicencio 2012; Brun-Aguerre et al. 2016 and Mohsen Bahmani-Oskooee & Amirhossein Mohammadian 2017. We allow nonlinearity and asymmetry as follows:

$$\begin{aligned} \Delta lcp_{i,t} = & \alpha_i + \beta_i lcp_{i,t-1} + \Theta_i^+ ler_{i,t-1}^+ + \Theta_i^- ler_{i,t-1}^- + \zeta_i lmon_{i,t-1} + \vartheta_i gap_{i,t-1} + \eta_i loil_{i,t-1} + \sum_{k=1}^{m-1} \vartheta_{i,k} \Delta lcp_{i,t-k} \\ & + \sum_{k=0}^{n-1} \theta_{i,k}^+ \Delta ler_{i,t-k}^+ + \sum_{k=0}^{p-1} \theta_{i,k}^- \Delta ler_{i,t-k}^- + \sum_{k=0}^{q-1} \chi_{i,k} \Delta lmon_{i,t-k} + \sum_{k=0}^{r-1} \mu_{i,k} \Delta gap_{i,t-k} + \sum_{k=0}^{s-1} \sigma_{i,k} \Delta loil_{i,t-k} + \xi_{i,t} \end{aligned} [2]$$

Where  $\Delta$  is the difference operator,  $gap$  is the output gap,  $ler^+$  and  $ler^-$  represent positive and negative partial sum of exchange rate denoting local currency depreciations (positive exchange rate changes) and local currency appreciations (negative exchange rate changes) respectively;  $\alpha_i$  refers to each country' specific intercept;  $\beta_i, \Theta_i^+, \Theta_i^-, \xi_i, \vartheta_i, \eta_i, \theta_i^+, \theta_i^-, \chi_i, \mu_i$  and  $\sigma_i$  are coefficients to be estimated and  $\xi_{i,t} \sim \text{IID}(0, \sigma^2)$ ;  $m, n, p, q, r$  and  $s$  are the optimal lags based on the general to specific approach and the Akaike Information Criterion (AIC).

In addition, the deviation of the nominal GDP from its Hodrick-Prescott filtered trend is utilized to compute the output gap variable ( $gap$ ). With regards to equation [2], the long-term ERPT elasticities are calculated by:  $\Omega^+ = -(\Theta_i^+ / \beta_i)$  and  $\Omega^- = -(\Theta_i^- / \beta_i)$  showing the long-term effects of depreciation and appreciation of the local currency on domestic price respectively. On the contrary,  $\theta_{i,k}^+$  and  $\theta_{i,k}^-$  are coefficients indicating the short-term effects of depreciation and appreciation on consumer prices index.

Following the modeling framework of Shin et al. (2014), the decompositions of the partial sum of exchange rate variable ( $ler$ ) into positive changes ( $ler^+$ ) and negative changes ( $ler^-$ ) are below computed:

$$ler_{i,t}^+ = \sum_{k=1}^t \Delta ler_{i,k}^+ = \sum_{k=1}^t \max(\Delta ler_{i,k}, 0) \quad \text{and} \quad ler_{i,t}^- = \sum_{k=1}^t \Delta ler_{i,k}^- = \sum_{j=1}^t \min(\Delta ler_{i,k}, 0),$$

Where  $ler_{i,t}^+$  and  $ler_{i,t}^-$  denote local currency depreciations and appreciations effects respectively..

### 3.2. Exchange rate pass-through estimation per country

Our analysis is conducted following three steps. First, we perform three common unit root tests on each variable per country: Augmented Dickey Fuller (ADF, 1981), Phillips-Perron (PP, 1988) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS, 1992). These tests are carried out after the analysis of the descriptive statistics of the variables. The null hypothesis ( $H_0$ ) of the ADF and PP tests supports the evidence of non-stationary variable against the alternative ( $H_1$ ) of stationary variable, whereas KPSS tests the null hypothesis ( $H_0$ ) of a stationary variable against the alternative ( $H_1$ ) of non-stationary variable. Second, we estimate the NARDL model [2] for each country following the general to specific method with a maximum lag length 4, dropping all insignificant variables from the model.

Thereby we investigate the existence of a long-term relationship in the model [2] using two approaches: Banerjee et al. (1998)'s t-test and Pesaran et al. (2001)'s F-test, respectively. The former ( $t_{BDM}$ ) tests the null hypothesis of  $\beta_i = 0$  against the one-sided alternative hypothesis  $\beta_i < 0$ , while the latter ( $F_{PSS}$ ) tests the null hypothesis of no cointegration i.e.  $\beta_i = \Theta_i^+ = \Theta_i^- = \eta_i = 0$  against the alternative of evidence of long-term relationship:  $\beta_i \neq \Theta_i^+ \neq \Theta_i^- \neq \eta_i \neq 0$ .

We compare the computed t-test and F-test to the critical values of Banerjee et al. (1998) and Pesaran et al. (2001) respectively. As a guideline for the tests, there is a long-term relationship between the variables if the computed t-statistic and F-statistic are greater than the upper critical values found in Banerjee et al. (1998) and Pesaran et al. (2001). On the contrary, the evidence of no long-term cointegration cannot be rejected when the t-statistic and F-statistic fall below the respective lower critical bounds. Moreover, we test the general hypothesis of symmetric exchange rate changes in model [2] both in long-term and short-term by performing Wald tests:

$\Omega^+ = \Omega^-$  and  $\sum_{k=0}^{n-1} \theta_{i,k}^+ = \sum_{k=0}^{n-1} \theta_{i,k}^-$  respectively. Thus, the model [2] can be rewritten with some restrictions allowing the evidence of either long-term symmetry, short-term symmetry or both long-term and short-term symmetries with respect to the results of Wald tests. When the results of Wald tests cannot reject the hypothesis of long-term symmetry, the NARDL model [2] is rewritten as follows:

$$\begin{aligned} \Delta lcp_{i,t} = & \alpha_i + \beta_i lcp_{i,t-1} + \Theta_i^+ ler_{i,t-1} + \zeta_i lmon_{i,t-1} + \vartheta_i gap_{i,t-1} + \eta_i loil_{i,t-1} + \sum_{k=1}^{m-1} \vartheta_{i,k} \Delta lcp_{i,t-k} \\ & + \sum_{k=0}^{n-1} \theta_{i,k}^+ \Delta ler_{i,t-k}^+ + \sum_{k=0}^{p-1} \theta_{i,k}^- \Delta ler_{i,t-k}^- + \sum_{k=0}^{q-1} \chi_{i,k} \Delta lmon_{i,t-k} + \sum_{k=0}^{r-1} \mu_{i,k} \Delta gap_{i,t-k} + \sum_{k=0}^{s-1} \sigma_{i,k} \Delta loil_{i,t-k} + \xi_{i,t} \dots [3] \end{aligned}$$

where model [3] describes the long-term symmetry between exchange rate and consumer price index with short-term asymmetry. The two other restricted NARDL models can be formulated by:

$$\begin{aligned} \Delta lcp_{i,t} = & \alpha_i + \beta_i lcp_{i,t-1} + \Theta_i^+ ler_{i,t-1}^+ + \Theta_i^- ler_{i,t-1}^- + \zeta_i lmon_{i,t-1} + \vartheta_i gap_{i,t-1} + \eta_i loil_{i,t-1} + \sum_{k=1}^{m-1} \vartheta_{i,k} \Delta lcp_{i,t-k} \\ & + \sum_{k=0}^{n-1} \theta_{i,k} \Delta ler_{i,t-k} + \sum_{k=0}^{q-1} \chi_{i,k} \Delta lmon_{i,t-k} + \sum_{k=0}^{r-1} \mu_{i,k} \Delta gap_{i,t-k} + \sum_{k=0}^{s-1} \sigma_{i,k} \Delta loil_{i,t-k} + \xi_{i,t} \dots [4] \end{aligned}$$

$$\begin{aligned} \Delta lcp_{i,t} = & \alpha_i + \beta_i lcp_{i,t-1} + \Theta_i ler_{i,t-1} + \zeta_i lmon_{i,t-1} + \vartheta_i gap_{i,t-1} + \eta_i loil_{i,t-1} + \sum_{k=1}^{m-1} \vartheta_{i,k} \Delta lcp_{i,t-k} \\ & + \sum_{k=0}^{n-1} \theta_{i,k} \Delta ler_{i,t-k} + \sum_{k=0}^{q-1} \chi_{i,k} \Delta lmon_{i,t-k} + \sum_{k=0}^{r-1} \mu_{i,k} \Delta gap_{i,t-k} + \sum_{k=0}^{s-1} \sigma_{i,k} \Delta loil_{i,t-k} + \xi_{i,t} \dots [5] \end{aligned}$$

where model [4] shows the long-term asymmetry between exchange rate and local price change associated with short-term symmetry; while both long-term and short-term symmetries are depicted in model [5]. Therefore, following Brun-Aguerre et al. (2016), we formulate six hypothesis:

*Hypothesis 1:* symmetric long-term ERPT i.e.  $H_0^1 : \Omega_i^+ = \Omega_i^-$  against  $H_A^1 : \Omega_i^+ \neq \Omega_i^-$

*Hypothesis 2* assumes zero ERPT for depreciations ( $\Omega_i^+$ ) or appreciations ( $\Omega_i^-$ ) in the long-term i.e.  $H_0^2 : \Omega_i^+ = 0, (\Omega_i^- = 0)$  against  $H_A^2 : \Omega_i^+ \neq 0, (\Omega_i^- \neq 0)$

*Hypothesis 3* supposes complete long-term ERPT for depreciations or appreciations,  $H_0^3 : \Omega_i^+ \geq 1, (\Omega_i^- \geq 1)$  against  $H_A^3 : \Omega_i^+ < 1, (\Omega_i^- < 1)$

*Hypothesis 4,*  $H_0^4 : \sum_{k=0}^{n-1} \theta_{i,k}^+ = \sum_{k=0}^{\theta-1} \theta_{i,k}^-$  against  $H_A^4 : \sum_{k=0}^{n-1} \theta_{i,k}^+ \neq \sum_{k=0}^{\theta-1} \theta_{i,k}^-$

*Hypothesis 5,*  $H_0^5 : \sum_{k=0}^{n-1} \theta_{i,k}^+ = 0, (\sum_{k=0}^{\theta-1} \theta_{i,k}^- = 0)$  against  $H_A^5 : \sum_{k=0}^{n-1} \theta_{i,k}^+ \neq 0, (\sum_{k=0}^{\theta-1} \theta_{i,k}^- \neq 0)$

*Hypothesis 6,*  $H_0^6 : \sum_{k=0}^{n-1} \theta_{i,k}^+ \geq 1, (\sum_{k=0}^{\theta-1} \theta_{i,k}^- \geq 1)$  against  $H_A^6 : \sum_{k=0}^{n-1} \theta_{i,k}^+ < 1, (\sum_{k=0}^{\theta-1} \theta_{i,k}^- < 1)$

Where: Hypothesis 4 supports a symmetrical pass-through in the short-term whereas Hypothesis 5 and Hypothesis 6 support a zero pass-through during the short-term and a complete pass-through respectively with respect to depreciations and appreciations.

Finally, we estimate the appropriate NARDL models for each country based on the results of the symmetry test and we obtain recursively the cumulative dynamic multipliers from the specific NARDL models employing the procedure of Shin et al. (2014) as follows:

$$m_{i,k}^+ = \sum_{k=0}^q \frac{\partial dlcp_{i,t+k}}{\partial dler_{i,t-1}^+}, m_{i,k}^- = \sum_{k=0}^q \frac{\partial dlcp_{i,t+k}}{\partial dler_{i,t-1}^-}, q = 0, 1, 2, 3, \dots, \infty$$

Where  $q \rightarrow \infty, m_{i,k}^+ \rightarrow \Omega^+$  and  $m_{i,k}^- \rightarrow \Omega^-$  with  $\Omega^+$  and  $\Omega^-$  the long-term pass-through coefficients for depreciations and appreciations respectively above defined. The dynamic multipliers show the evolution of consumer price index over time in response to a positive change (depreciation) and negative change (appreciation) of exchange rate.

### 3.3. Panel pass-through estimation

In this section, we first conduct the cross-sectional dependence analysis between countries which may arise from unobserved common factors (psychological, economic and social norms) by using four tests. The Friedman's test (1937) is non-parametric and based on the Spearman's rank correlation. The test statistic is thereby computed:

$$R_{ave} = \frac{2}{K(K-1)} \sum_{i=1}^{K-1} \sum_{j=i+1}^K \hat{r}_{ij}, \text{ with } r_{ij} \text{ the coefficient of Spearman correlation and } K \text{ denotes the}$$

cross-section dimension.

Breusch and Pagan (1980) suggested an alternative statistic using Lagrange Multiplier which is appropriate for large time periods ( $T > K$ ) and relatively short cross section dimension  $K$  and tests the null hypothesis of no cross-sectionally correlated errors:

$$CD_{LM} = T \sum_{i=1}^{K-1} \sum_{j=i+1}^K \hat{\rho}_{ij}^2, \text{ where } \hat{\rho}_{ij} \text{ is the estimated pairwise correlation of the residuals.}$$

In addition, Frees (1995) provides another test of cross-sectional dependence which can deal with the false hypothesis in the case of many disturbances cross-sectionally correlated. Frees's statistic contains the coefficients of the squared rank correlation and is thereby calculated:

$$FT = K \left\{ R_{ave}^2 - (T-1)^{-1} \right\} \xrightarrow{d} Q \text{ distribution and } R_{ave}^2 = \frac{2}{K(K-1)} \sum_{i=1}^{K-1} \sum_{j=i+1}^K r_{ij}^{\wedge 2}.$$

On the other hand, Pesaran (2004) suggested a modified version of Breusch and Pagan (1980) statistic and tests the null hypothesis of zero cross section correlation among residuals when  $T < K$ . The Pesaran's CD statistic is computed as follows:

$$CD = \sqrt{\frac{2T}{K(K-1)}} \left( \sum_{i=1}^{K-1} \sum_{j=i+1}^K \sqrt{T_{ij}} \hat{\rho}_{ij} \right) \text{ for the unbalanced panels, } CD \rightarrow N(0,1) \text{ for } T \text{ large and } K \rightarrow \infty.$$

Thus, Friedman (1937), Pesaran (2004) and Frees (1995) tests are useful cross-sectional dependence tests when  $T < K$  while Breusch and Pagan (1980) LM test is suitable for  $T > K$

Furthermore, we implement the panel ERPT using two common panel estimators: the Feasible Generalized Least Squares (FGLS) estimator of Parks (1967) and Kmenta (1986) and the Pooled OLS regression with Driscoll and Kraay (1998)'s standard errors which are convenient in the case of cross-sectional dependence (autocorrelation) and heteroscedasticity among the residuals between panel units. However, Parks and Kmenta FGLS method is appropriate when the time period dimension ( $T$ ) is greater than the cross section dimension ( $K$ ). In fact, FGLS estimator becomes not workable when  $K > T$  because it will be impossible to get a non-singular estimated coefficients of the cross-sectional covariances matrix of type  $K \times K$ , as well as to produce acceptable standard error coefficients as argued by Beck and Katz (1995). Besides, Driscoll and Kraay (1998)'s standard errors is a nonparametric method to estimate standard errors which are robust to heteroscedasticity and autocorrelated errors between panel units and can also be implemented for  $T < K$  but not with a very small time period dimension since this estimator is based on large  $T$  asymptotics. Besides, the approach of Driscoll and Kraay (1998) utilizes the Newey and West (1987) method to the cross-sectional averages of the moment conditions. Finally, a pooled OLS regression is performed by using the standard errors of Driscoll and Kraay (1998) and following the procedure of Hoechle (2007) which is convenient for the unbalanced and balanced panel data and considers the possibility of cross-sectional dependence among the countries.

## 4. Empirical results and Discussions

### 4.1. Results of the pass-through estimations per country

The primary results start with some descriptive statistics on the variables for each country of our sample as shown below in Table 1 and Table 2. Thus, the SSA region experiences more volatility in the exchange rate across countries, as reflected by higher values of the standard deviations.

**Table 1.** Descriptive statistics for the CFA franc zone

Country	Period	Nominal exchange rate				Consumer Price Index		Output gap		Money supply	
		Mean	Std.Dev	(ler)		Mean	Std.Dev	Mean	Std.Dev	Mean	Std.Dev
				Depr (+)	Appr (-)						
		$dler_t$ (%)		$dlcpi_t$ (%)		$gap_t$ (%)		$dmon_t$ (%)			
<b>CFA franc zone (14)</b>	1990Q2-2017Q4	0.630	8.249	51.98	48.02	1.047	3.539	-2.548	56.625	0.231	6.795
<b>Waemu (N<sub>w</sub>=8)</b>	1990Q2-2017Q4	0.595	8.197	51.48	48.52	1.067	3.664	-3.451	40.905	0.185	7.601
<i>Benin</i>	1992Q1-2017Q4	0.655	8.280	52.43	47.57	1.037	2.943	-0.099	8.627	0.191	3.946
<i>Burkina Faso</i>	1990Q1-2017Q4	0.587	8.224	51.35	48.65	0.719	2.241	-0.118	8.419	0.839	4.099
<i>Cote d'Ivoire</i>	1990Q1-2017Q4	0.587	8.224	51.35	48.65	0.886	2.027	-0.012	2.840	0.201	4.067
<i>Guinea-Bissau</i>	1990Q1-2017Q4	0.587	8.224	51.35	48.65	2.994	6.314	-26.854	111.282	-1.312	18.486
<i>Mali</i>	1990Q1-2017Q4	0.587	8.224	51.35	48.65	0.691	2.770	-0.052	4.843	0.164	4.038
<i>Niger</i>	1990Q1-2017Q4	0.587	8.224	51.35	48.65	0.679	3.234	-0.194	9.586	0.243	5.730
<i>Senegal</i>	1990Q1-2017Q4	0.587	8.224	51.35	48.65	0.627	2.522	-0.042	4.232	0.726	2.392
<i>Togo</i>	1990Q1-2017Q4	0.587	8.224	51.35	48.65	0.896	4.646	-0.000	8.556	0.434	3.768
<b>Cemac (N<sub>c</sub>=6)</b>	1990Q2-2017Q4	0.679	8.326	52.66	47.34	1.018	3.361	-1.303	72.963	0.295	5.498
<i>Cameroon</i>	1990Q1-2017Q4	0.587	8.224	51.35	48.65	0.808	2.173	-0.025	2.820	0.000	3.463
<i>Central African Rep.</i>	1990Q1-2015Q4	0.727	8.463	53.40	46.60	1.404	3.285	-8.599	180.258	0.501	4.888
<i>Chad</i>	1990Q1-2015Q4	0.727	8.463	53.40	46.60	0.961	4.902	-0.369	13.719	-0.000	4.807
<i>Congo Rep.</i>	1990Q1-2015Q4	0.727	8.463	53.40	46.60	1.085	3.248	-0.181	11.021	0.736	4.067
<i>Equatorial Guinea</i>	1990Q1-2017Q4	0.587	8.224	51.35	48.65	1.332	3.214	1.085	17.733	0.104	9.688
<i>Gabon</i>	1990Q1-2016Q4	0.730	8.334	53.27	46.73	0.532	2.837	-0.058	4.248	0.456	3.192
Oil price ( $dloil_t$ (%))	1990Q1-2017Q4	0.793	8.326								

Note:  $d$  is the first difference operator of the variable in logarithmic form i.e  $dlex = lex_t - lex_{t-1}$ ;  $dlcpi = lcp_i - lcp_{i-1}$ ;  $dmon_t = lmon_t - lmon_{t-1}$  and  $dloil = loil_t - loil_{t-1}$ ; *Std.Dev* is the variable's standard deviation; *Depr (+)* and *Appr (-)* stand for currency depreciation and currency appreciation respectively i.e the percentage of quarter during which there is positive (*Depr (+)*) and negative (*Appr (-)*) exchange rate changes. Authors' computations by using Eviews 9.

Especially, the nominal exchange rate is more volatile in Congo Democratic Republic (28.78%), Angola (23.57%) than in other countries such as Cabo Verde (5.21%) and Mauritius (4.24%).

On the other hand, the same level of exchange rate volatility (8.24%, on average in CFA franc zone) in Waemu and Cemac countries can be explained by the fact that the two regions belong to the CFA franc zone with two currencies (West African CFA, XOF and Central African CFA francs, XAF respectively for Waemu and Cemac sub-regions).

**Table 2.** Descriptive statistics for the other Sub-Saharan African countries

Country	Period	Nominal exchange rate				Consumer Price Index		Output gap		Money supply	
		$(ler)$				$(lcp_i)$		$(gap)$		$(mon)$	
		Mean	Std.Dev	Depr (+)	Appr (-)	Mean	Std.Dev	Mean	Std.Dev	Mean	Std.Dev
Other SSA ( $N=26$ )		2.610	10.919	67.78	32.22	3.135	6.327	-2.157	114.791	0.502	4.208
Angola	1996Q1-2017Q4	9.575	23.576	87.36	12.64	11.872	14.491	-0.062	3.777	-0.150	5.775
Botswana	1990Q1-2017Q4	1.484	4.996	66.67	33.33	1.990	1.045	-0.022	3.243	0.691	5.070
Cabo Verde	1990Q1-2017Q4	0.196	5.217	52.25	47.75	0.776	1.789	-6.168	56.870	0.990	2.489
Comoros	2000Q1-2013Q4	-0.667	5.188	45.45	54.55	0.799	3.659	0.030	5.457	1.615	3.677
Congo, D. Rep	1995Q1-2016Q4	11.864	28.785	77.01	22.99	11.203	19.856	-0.140	5.218	0.837	5.129
Ethiopia	1990Q1-2008Q4	2.094	10.249	97.33	2.67	2.127	4.690	-0.054	3.771	0.131	3.381
Gambia	1990Q1-2014Q4	1.708	6.410	69.70	30.30	1.373	1.684	-2.022	22.038	0.748	5.737
Ghana	1990Q1-2017Q4	4.497	6.545	96.40	3.60	4.341	3.588	-0.050	3.903	0.701	3.737
Guinea	2004Q1-2016Q4	2.997	8.574	79.39	19.61	3.822	2.933	-0.027	5.971	0.506	5.907
Kenya	1990Q1-2017Q4	1.353	6.414	59.46	40.54	2.758	3.334	-0.036	3.076	0.260	2.424
Lesotho	1990Q1-2017Q4	1.385	7.069	60.36	39.64	1.867	2.975	-36.104	452.383	-0.098	3.014
Liberia	2001Q1-2015Q4	1.127	7.538	72.88	27.12	2.411	3.246	40.344	312.087	1.720	5.730
Madagascar	1990Q1-2017Q4	2.117	8.882	57.66	42.34	2.726	3.415	-0.030	5.431	0.646	3.136
Malawi	1990Q1-2016Q4	5.158	11.082	76.64	23.36	4.733	7.091	-0.179	12.304	0.157	6.208
Mauritius	1990Q1-2017Q4	0.720	4.247	61.26	38.74	1.335	1.240	-0.028	2.638	0.574	1.444
Mozambique	2007Q1-2017Q4	1.885	7.272	60.47	39.53	1.990	2.408	-0.043	4.029	1.286	2.901
Namibia	2002Q1-2015Q4	0.133	7.704	49.21	50.79	1.432	0.931	-61.524	3.719	0.600	3.986
Nigeria	1990Q1-2016Q4	3.409	15.658	71.03	28.97	4.117	4.544	-0.091	4.900	0.132	7.624
Rwanda	1990Q1-2016Q4	2.187	7.755	67.29	32.71	1.891	2.594	-1.113	20.016	0.254	4.436
Sao T. and Prin.	2001Q1-2017Q4	1.264	4.147	64.18	35.82	2.989	2.061	-0.002	3.482	0.379	3.395
Seychelles	1990Q1-2017Q4	0.820	8.297	65.77	34.23	0.934	3.384	10.771	160.238	0.695	3.484
South Africa	1990Q1-2017Q4	1.385	7.069	60.36	39.64	1.630	1.075	-0.012	1.601	0.322	1.431
Swaziland	1990Q1-2016Q4	1.534	7.108	61.68	38.32	1.912	2.057	-0.577	11.681	0.401	3.158
Tanzania	1990Q1-2016Q4	2.258	4.610	73.83	26.17	2.946	4.583	-0.091	4.079	0.000	2.363
Uganda	1993Q1-2017Q4	1.102	4.946	59.60	40.40	1.574	2.046	-0.116	3.694	0.941	3.477
Zambia	1990Q1-2017Q4	5.226	15.458	67.57	32.43	6.350	7.394	-0.103	4.264	0.136	4.439
Oil price ( $dloil_t$ (%))	1990Q1-2017Q4	0.793	8.326								

**Note:**  $d$  is the first difference operator of the variable in logarithmic form i.e  $dlex_t = lex_t - lex_{t-1}$ ;  $d_lcp_i = lcp_i - lcp_{i-1}$ ,  $d_lmon_t = lmon_t - lmon_{t-1}$  and  $dloil_t = loil_t - loil_{t-1}$ ; *Std.Dev* is the variable's standard deviation; *Depr (+)* and *Appr (-)* stand for currency depreciation and currency appreciation respectively i.e the percentage of quarter during which there is positive (*Depr (+)*) and negative (*Appr (-)*) exchange rate changes over the sample. Authors' computations by using Eviews 9.

Although these two regions have a fixed exchange rate to the Euro and have always been at parity (so that they share almost a common monetary value against other currencies), they are theoretically and institutionally separated and could have different monetary policies which may influence the value of their respective currencies at any time.

Besides, The results of Table 1 and Table 2 show that most SSA countries present a common trend in the exchange rate movements since there have been more depreciations (positive changes in exchange rate) than appreciations (negative changes in exchange rate) of their local currency over the sample period. The magnitudes for depreciations range from 45.45% (Comoros) to 97.33% (Ethiopia) except in the CFA franc zone (WAEMU and CEMAC) where the local currency depreciates by 51.98% on average across countries. These facts encourage more exports from SSA countries by the price competitiveness resulting from local currency depreciations. In addition, the results show a different pattern in price volatility with higher price volatility in Congo Democratic Republic (19.85%), Angola (14.49%); relatively less pronounced effects in Namibia (0.93%), and Botswana (1.04%). Prices deviation from its mean value is mostly less than 5% in the remaining countries, especially in the CFA franc zone (around 3.54% on average).

Furthermore, the results of the stationarity tests on each variable per country are depicted in Table 3 where we performed traditional unit root tests aforementioned in section 3 following a model with constant and no trend. Thus, we find evidence that all variables are almost stationary at first difference at any conventional significance level.

**Table 3.** Unit root analysis tests

Country	Nominal exchange rate ( <i>ler</i> )			Consumer Price Index ( <i>lcpi</i> )			Output gap ( <i>gap</i> )			Money supply ( <i>lmon</i> )		
	<u><i>ler<sub>t</sub></i></u>			<u><i>lcpi<sub>t</sub></i></u>			<u><i>gap<sub>t</sub></i></u>			<u><i>lmon<sub>t</sub></i></u>		
	ADF: H <sub>0</sub> =I(1)	PP H <sub>0</sub> =I(1)	KPSS H <sub>0</sub> =I(0)	ADF: H <sub>0</sub> =I(1)	PP H <sub>0</sub> =I(1)	KPSS H <sub>0</sub> =I(0)	ADF: H <sub>0</sub> =I(1)	PP H <sub>0</sub> =I(1)	KPSS H <sub>0</sub> =I(0)	ADF: H <sub>0</sub> =I(1)	PP H <sub>0</sub> =I(1)	KPSS H <sub>0</sub> =I(0)
<i>Benin</i>	-2.916**	-2.874***	0.201	-3.352**	-3.242**	1.152*	-5.434*	-3.225**	0.025	-1.173	-0.790	0.843*
<i>Burkina Faso</i>	-2.235	-2.210	0.357***	-1.935	-1.693	1.140*	-4.687*	-3.841*	0.025	0.870	0.220	0.923*
<i>Cote d'Ivoire</i>	-2.235	-2.210	0.357***	-3.045**	-2.344	1.127*	-4.369*	-3.575*	0.026	-1.060	-0.812	0.559**
<i>Guinea-Bissau</i>	-2.235	-2.210	0.357***	-3.383**	7.297*	0.911*	-4.937*	-4.412*	0.263	-1.623	-3.692*	0.512**
<i>Mali</i>	-2.235	-2.210	0.357***	-2.785***	-1.465	1.122*	-3.060**	-2.746***	0.029	-2.395	-2.400	0.749
<i>Niger</i>	-2.235	-2.210	0.357***	-2.585***	-1.221	1.081*	-4.739*	-3.786*	0.027	-1.104	-0.665	0.520**
<i>Senegal</i>	-2.235	-2.210	0.357***	-1.763	-1.697	1.081*	-4.345*	-3.846*	0.027	1.720	0.624	1.093*
<i>Togo</i>	-2.235	-2.210	0.357***	-2.023	-1.655	1.063*	-4.924*	-3.434*	0.025	0.074	-0.125	0.772*
<i>Cameroon</i>	-2.235	-2.210	0.357***	-1.930	-1.661	1.121	-5.832*	-3.877*	0.028	-1.644	-1.237	0.518**
<i>Central African Rep.</i>	-2.076	-2.048	0.374***	1.496	1.532	1.170	-9.055*	-9.014*	0.045	-1.938	-1.300	0.234
<i>Chad</i>	-2.076	-2.048	0.374***	-1.904	-1.452	1.141	-4.718*	-2.950**	0.038	-1.252	-2.236	0.191
<i>Congo Rep.</i>	-2.076	-2.048	0.374***	-1.165	-1.124	1.108	-3.486**	-3.435**	0.022	0.252	2.611	0.620
<i>Equatorial Guinea</i>	-2.076	-2.048	0.374***	-5.251*	-1.577	1.177	-7.638*	-7.638*	0.041	-0.299	-1.648	0.344
<i>Gabon</i>	-2.094	-2.062	0.382***	-0.842	-0.898	1.014	-2.697***	-3.259**	0.030	-0.569	-0.983	0.828

**Table 3.** Unit root tests (continued)

Country	Nominal exchange rate ( <i>ler</i> )			Consumer Price Index ( <i>lcpi</i> )			Output gap ( <i>gap</i> )			Money supply ( <i>lmon</i> )		
	<u><i>ler<sub>t</sub></i></u>			<u><i>lcpi<sub>t</sub></i></u>			<u><i>gap<sub>t</sub></i></u>			<u><i>lmon<sub>t</sub></i></u>		
	ADF: H <sub>0</sub> =I(1)	PP H <sub>0</sub> =I(1)	KPSS H <sub>0</sub> =I(0)	ADF: H <sub>0</sub> =I(1)	PP H <sub>0</sub> =I(1)	KPSS H <sub>0</sub> =I(0)	ADF: H <sub>0</sub> =I(1)	PP H <sub>0</sub> =I(1)	KPSS H <sub>0</sub> =I(0)	ADF: H <sub>0</sub> =I(1)	PP H <sub>0</sub> =I(1)	KPSS H <sub>0</sub> =I(0)
Angola	-6.989*	-5.277*	0.843*	-2.464	-7.545*	1.000*	-3.496**	-3.398**	0.049	-1.919	-1.333	0.766*
Botswana	-1.488	-1.468	1.140*	-1.241	-4.866*	1.220*	-2.445	-3.375**	0.029	-1.020	-1.895	0.891*
Cabo Verde	-1.935	-1.951	0.193	-1.853	-3.923*	1.156*	-5.907*	-9.570*	0.445	-2.089	-2.077	1.008*
Comoros	-1.547	-1.547	0.649**	-1.779	-1.453	0.896*	-4.281*	-2.779***	0.050	-0.820	-2.837***	0.889
Congo Dem. Rep.	-2.121	-4.526*	0.948*	-4.518*	-4.265*	0.943*	-2.695***	-3.438**	0.056	-0.824	0.078	0.852
Ethiopia	-1.124	-2.178	0.909*	0.138	0.565	0.996*	-3.856*	-3.134**	0.042	-1.555	-1.497	0.887*
Gambia	-0.462	-0.109	1.130*	-0.075	-0.358	1.209*	-2.480	-3.341**	0.076	-2.045	-0.283	1.120*
Ghana	-2.052	-1.922	1.163*	-2.918**	-2.626***	1.192*	-3.845*	-3.461**	0.033	-1.973	-2.504	0.917*
Guinea	-0.369	-2.656***	0.902*	-4.525*	-4.274*	0.953*	-3.899*	-2.590	0.047	-1.960	-1.437	0.568
Kenya	-2.974**	-3.070**	1.029*	-1.999	-2.779**	1.205*	-4.165*	-3.204**	0.036	-2.614***	-2.742***	0.628**
Lesotho	-1.697	-1.329	1.025*	-1.862	-2.690**	1.052*	-11.187*	-12.343*	0.129	-1.435	-2.547	0.243*
Liberia	-0.899	-2.024	0.908*	-0.911	-2.596***	0.970*	-7.664*	-7.665*	0.136	-3.930*	-1.020	0.805*
Madagascar	-1.767	-1.776	1.106*	-2.088	-2.137	1.184*	-3.741*	-4.648*	0.023	-1.006	-3.317**	1.001*
Malawi	-2.185	-1.053	1.119*	-2.424	-1.560	1.136*	-5.075*	-3.872*	0.025	-1.737	-1.049	0.299
Mauritius	-1.696	-1.696	1.059*	-3.320**	-3.222**	1.217*	-2.310	-3.670*	0.029	-1.146	-1.486	1.165*
Mozambique	-0.859	-0.368	0.626**	-0.323	-0.343	0.823*	-3.682*	-2.561	0.076	-1.172	-1.916	0.763*
Namibia	-0.950	-1.161	0.654**	-0.088	-0.841	1.023	-5.108*	-4.446*	0.615**	-1.711	-1.393	0.684**
Nigeria	-1.606	-1.606	1.053*	-1.984	-3.039**	1.105*	-3.624*	-3.084**	0.038	-3.168**	-2.617***	0.110
Rwanda	-2.827***	-3.379**	1.054*	-0.849	-1.720	1.200*	-3.588*	-3.059**	0.041	-3.109**	-1.995	0.575**
Sao Tome & Prin.	-1.286	-1.292	1.024*	-1.843	-1.827	1.051*	-4.318*	-3.111**	0.042	-2.565	-2.397	0.611**
Seychelles	-0.250	-0.374	1.018*	0.047	0.219	1.108*	-5.102*	-5.132*	0.059	-2.451	-2.212	0.248
South Africa	-1.697	-1.329	1.025*	-2.679***	-3.577*	1.214*	-3.591*	-3.008**	0.036	-1.394	-0.957	1.040*
Swaziland	-0.990	-1.019	0.991*	-2.334	-2.434	1.180*	-3.564*	-3.298**	0.043	-0.706	-0.567	0.371***
Tanzania	-3.460**	-3.020**	1.122*	-2.626***	-4.070*	1.104*	-3.699*	-3.945*	0.044	-3.365**	-2.054	0.308
Uganda	-0.512	0.116	1.095*	0.081	0.252	1.195*	-2.507	-7.135*	0.058	-2.071	-0.125	0.772*
Zambia	-5.974*	5.648*	0.976*	-5.107*	-8.642*	1.102*	-3.561*	-3.236**	0.045	-2.071	-2.761***	1.125*
<i>Oil price</i>	ADF:	PP	KPSS									
<i>loil</i>	-1.174	-1.011	0.973*									

Note: *ler*, *lcpi*, *lmon* and *loil* denote the logarithmic form of the nominal exchange rate, consumer price index, money supply and price of crude oil respectively. ADF and PP respectively represent Augmented Dickey-Fuller and Phillips-Perron unit root tests while KPSS denotes Kwiatkowski-Phillips-Schmidt-Shin test statistic. The null hypothesis H<sub>0</sub>=I(1) of the ADF and PP tests depicts that the variable is stationary at first difference against the alternative hypothesis of stationarity at level. However, the null hypothesis H<sub>0</sub>=I(0) for the KPSS test implies that the variable is stationary at level against the alternative hypothesis of stationary variable at first difference. The symbols \*, \*\*, \*\*\* shows the rejection of the null hypothesis respectively at 1%, 5% and 10% level of significance. Authors' computations by using Eviews 9.

Thereby, the nonlinear autoregressive distributed lags (NARDL) framework is justified to investigate the asymmetric exchange rate pass-through (ERPT) into prices since none variable is integrated of order 2.

**Table 4.** Cointegration tests for CFA franc zone

Countries	Unrestricted NARDL				Restricted NARDLs			
	NARDL model [2]		NARDL model [3]		NARDL model [4]		NARDL model [5]	
	SrA & LrA		SrA & LrS		SrS & LrA		SrS & LrS	
	tBDM	F <sub>PSS</sub>	tBDM	F <sub>PSS</sub>	tBDM	F <sub>PSS</sub>	tBDM	F <sub>PSS</sub>
Waemu(N <sub>w</sub> =8)								
<i>Benin</i>	-1.682	4.252§	-1.463	6.070‡	-1.198	7.016‡	-3.743†	3.092
<i>Burkina Faso</i>	-4.314§	3.346	-3.856†	3.213	-4.573§	3.754†	-3.743†	3.092
<i>Cote d'Ivoire</i>	-1.917	2.123	0.285	1.880	-5.515‡	5.934‡	-1.308	2.254
<i>Guinea-Bissau</i>	-5.637‡	8.895‡	-6.024‡	10.935‡	-5.333‡	8.164‡	-5.718‡	9.898‡
<i>Mali</i>	-7.187‡	10.217‡	-3.215	2.900	-5.593‡	7.371‡	-2.148	3.479
<i>Niger</i>	-5.422‡	5.552‡	-5.167‡	5.805‡	-5.786‡	6.128‡	-5.302‡	6.018‡
<i>Senegal</i>	-4.277§	3.365	-4.153§	5.085§	-1.956	5.563‡	-1.090	6.178‡
<i>Togo</i>	-3.521	3.782†	-2.978	4.232§	-3.473	5.395‡	-2.828	4.346§
Cemac (N <sub>c</sub> =6)								
<i>Cameroon</i>	-4.370§	6.517‡	1.154	0.567	-5.299‡	10.009‡	-1.749	2.564
<i>Central African Rep.</i>	-0.532	3.399	0.838	4.377§	-1.133	1.592	0.328	2.444
<i>Chad</i>	-6.597‡	8.501‡	-5.337‡	7.000‡	-6.057‡	8.832‡	-5.080‡	6.460‡
<i>Congo Rep.</i>	-4.355§	6.594‡	-2.719	4.540§	-2.787	2.443	-1.650	2.748
<i>Equatorial Guinea</i>	-5.902‡	7.451‡	-2.203	3.412	-4.915‡	5.845‡	-1.384	1.576
<i>Gabon</i>	-4.602§	6.210‡	-2.029	1.318	-3.544	3.004	-2.866	2.178

**Note:** SrA: Short-term Asymmetry; LrA: Long-term Asymmetry; SrS: Short-term Symmetry and LrS denote Long-term Symmetry models; *t*<sub>BDM</sub> and *F*<sub>PSS</sub> denote the Banerjee et al (1998) t-test and the Pesaran et al (2001) F-test respectively. Given, the small sample size, we use the critical values of Narayan (2005) following the specific sample size of each country (see Appendix A **Table A.1**). For instance, we use the critical values with *n* = 80 observations for countries with *n* ≥ 80. For these countries, the critical values [lower bound: I(0); upper bound: I(1)] for *F*<sub>PSS</sub> test with *k* = 5 (*k* being the number of explanatory variables in the model namely *lex*, *lex*<sup>\*</sup>, *lmon*, *gap* and *loil*) for models [2] and [4] are [3.725; 5.163] at 1% , [2.787; 4.015] at 5% and [2.355; 3.500] at 10% significance levels but the similar critical values with *k* = 4 (*lex*, *lmon*, *gap* and *loil*) for models [3] and [5] are [4.096; 5.512] at 1% , [3.010; 4.216] at 5% and [2.548; 3.644] at 10%. The corresponding critical values for *t*<sub>BDM</sub> using t-Bounds test with *k* = 5 for models [2] and [4] are: [-3.43; -4.79] at 1%, [-2.86; -4.19] at 5% and [-2.57; -3.86] at 10%. The similar critical values for *t*<sub>BDM</sub> with *k* = 4 for models [3] and [5] are [-3.43; -4.60] at 1%, [-2.86; -3.99] at 5% and [-2.57; -3.66] at 10%. Values reported in the table are t-statistics for *t*<sub>BDM</sub> test and F-statistics for *F*<sub>PSS</sub>. The models have been estimated following the general to specific approach (uni-directional method and p-value backwards 10% significance level as stopping criteria) with maximum lag length 4 (see Campa and Goldberg, 2005; Delatte et al, 2012). The symbols †, § and ‡ show the significance at 10%, 5% and 1% levels respectively. Authors' computations by using Eviews 9.

Then, the cointegration analysis and the symmetry tests are implemented by using the different NARDL models to examine the long-term relationship between variables and determine the suitable model specification for each country from these tests.

**Table 5.** Cointegration tests for the other SSA countries

Countries	Unrestricted NARDL				Restricted NARDLs			
	NARDL model [2]		NARDL model [3]		NARDL model [4]		NARDL model [5]	
	SrA & LrA		SrA & LrS		SrS & LrA		SrS & LrS	
	tBDM	F <sub>PSS</sub>	tBDM	F <sub>PSS</sub>	tBDM	F <sub>PSS</sub>	tBDM	F <sub>PSS</sub>
Other( <i>N</i> <sub>O</sub> =26)								
Angola	-0.797	14.627†	-0.769	17.781†	-2.674	9.344†	-1.622	11.470†
Botswana	-2.145	6.572†	-2.840	14.743†	-2.334	4.082§	-1.938	14.237†
Cabo Verde	-4.602§	7.592†	-5.504†	9.469†	-4.393§	7.897†	-5.157§	9.452†
Comoros	-7.058†	10.040†	-5.265†	6.001†	-8.238†	11.705†	-6.497†	8.901†
Congo, Dem. Rep.	-3.246	16.544†	-1.823	24.557†	-0.226	4.757†	1.681	3.307
Ethiopia	-1.454	4.752§	2.776	9.477†	-1.588	4.257§	-1.806	3.781†
Gambia	-5.105†	8.456†	-3.547	6.682†	-5.617†	8.874†	-2.865	5.082†
Ghana	-2.051	1.850	-2.072	2.196	-1.618	1.485	-1.633	1.800
Guinea	4.273§	27.936†	-1.776	18.369†	0.460	6.912†	0.800	11.365†
Kenya	2.595	10.845†	-0.746	4.973§	2.865	10.538†	-0.789	4.423§
Lesotho	-0.419	3.763†	-1.178	4.529§	-0.608	5.090§	-2.072	5.999†
Liberia	-4.362§	6.276†	-3.714	4.010†	-4.137§	4.104†	0.471	1.159
Madagascar	-0.524	5.870†	-1.910	7.069†	-3.301	5.745†	-3.002	7.793†
Malawi	-3.672	7.609†	-3.686†	9.085†	-2.363	4.740§	-2.293	5.571†
Mauritius	-2.683	2.801	-2.223	2.325	-2.751	2.792	-1.802	2.438
Mozambique	-2.688	8.900†	-4.503†	11.843†	-1.845	11.138†	0.565	6.294†
Namibia	-3.144	3.703†	-0.978	1.449	-1.735	4.289§	-0.401	1.392
Nigeria	-6.595†	8.916†	-2.039	6.912†	-2.075	5.492†	-2.154	6.189†
Rwanda	-2.981	3.501†	-4.612§	5.470§	-4.412§	4.509§	-4.612§	5.470§
Sao Tome and Prin.	-3.151	3.547†	-3.681†	4.355§	-4.356§	6.041†	-5.478†	7.374†
Seychelles	-1.719	6.984†	-3.240	7.859†	-7.373†	15.031†	-7.098†	12.491†
South Africa	-3.345	3.561†	-1.470	2.800	-3.419	5.073§	-1.326	3.296
Swaziland	-1.922	2.293	-1.759	2.478	-1.922	2.293	-1.759	2.478
Tanzania	-1.645	5.296§	0.553	5.472†	-2.721	5.935†	0.402	4.453§
Uganda	-2.952	3.070	-1.023	1.626	-4.163†	4.538§	-1.575	2.316
Zambia	-2.708	4.153§	-2.852	4.407§	-3.767	9.404†	-2.492	6.644†

Note: see Table 4

Table 4 and Table 5 unveil the outcomes of the cointegration analysis. The results are mixed following the diverse specifications as well as the  $t_{BDM}$  of Banerjee et al (1998) and the  $F_{PSS}$  of Pesaran et al (2001)' test statistics. For instance, the evidence of long-term relationship among the variables depends on the model specification in many cases (Cote d'Ivoire, Mali, Central African Republic, Gabon, Liberia, South Africa and Uganda, etc...) and the significance of one or both  $t_{BDM}$  and  $F_{PSS}$  statistics (Botswana, Cabo Verde, Ethiopia, Madagascar, among others...) compared with their critical bounds values.

However, at least in one of the various NARDL models, the long-term relationship between consumer prices, exchange rates, money supply, output gap and oil price cannot be rejected since one or both  $t_{BDM}$  and  $F_{PSS}$  statistics are greater than the corresponding critical bounds values at the conventional level of significance in most cases. Additionally, the results of the symmetry tests in the short and long-term are presented in Table 6 and Table 7 for each country.

**Table 6.** Symmetry tests for CFA franc zone

Country	Short-run tests ( $W_{SR}$ ) $H_0: \sum_k^s \theta_{i,k}^- = \sum_k^l \theta_{i,k}^+$	Long-run tests ( $W_{LR}$ ): $H_0: \Omega^- = \Omega^+$	Unrestricted & Restricted NARDL models
Waemu ( $N_w=8$ )			
Benin <sup>(a)</sup>	66.787‡	6.121§	Rest. NARDL model [2]
Burkina Faso <sup>(a)</sup>	12.752‡	4.921§	Unr. NARDL model [2]
Cote d'Ivoire <sup>(c)</sup>	-	81.428‡	Rest. NARDL model [4]
Guinea-Bissau <sup>(a)</sup>	11.648‡	0.001	Rest. NARDL model [3]
Mali <sup>(a)</sup>	4.105§	78.592‡	Rest. NARDL model [2]
Niger <sup>(a)</sup>	1.348	0.213‡	Rest. NARDL model [4]
Senegal <sup>(a)</sup>	-0.034	0.248‡	Unr. NARDL model [4]
Togo <sup>(a)</sup>	1.613	7.754‡	Unr. NARDL model [4]
Cemac ( $N_c=6$ )			
Cameroon <sup>(a)</sup>	66.843‡	74.393‡	Unr. NARDL model [2]
Central Afr. Rep <sup>(b)</sup>	24.061‡	-	Rest. NARDL model [3]
Chad <sup>(a)</sup>	20.088‡	18.444‡	Rest. NARDL model [2]
Congo Rep <sup>(a)</sup>	6.035§	28.834‡	Rest. NARDL model [2]
Equatorial Guinea <sup>(a)</sup>	4.864§	134.545‡	Unr. NARDL model [2]
Gabon <sup>(a)</sup>	22.314‡	27.315‡	Rest. NARDL model [2]

Note:

$$\sum_k^s \theta_{i,k}^- (\sum_k^l \theta_{i,k}^+) \text{ is}$$

the short-term additive pass-through for appreciations (depreciations) while  $\Omega^-$  and  $\Omega^+$  are the corresponding long-term pass-through coefficients;  $W_{SR}$  and  $W_{LR}$  are the Wald tests for short-term additive and long-run symmetric ERPT respectively and the values represent their respective F-statistics; *Unr.* stands for unrestricted NARDL models while *Rest.* denotes the restricted NARDL models. The results of the cointegration analysis allows us to perform the Wald tests using the unrestricted <sup>(a)</sup>NARDL model [2] as a benchmark model and running after the restricted <sup>(b)</sup>NARDL model [3] and <sup>(c)</sup>NARDL model [4] in the suitable case following the general to specific approach (uni-directional method and p-value backwards 10% significance level as stopping criteria) with maximum lag length 4. The symbols †, § and ‡ show the significance (rejection of null hypothesis  $H_0$ ) at 10%, 5% and 1% levels respectively. Authors' computations by using Eviews 9.

The hypothesis ( $H_1^0$ ) of a long-term symmetrical exchange rate pass-through (ERPT) is rejected in thirty (30) out of forty (40) SSA countries. Therefore, the evidence of a long-term asymmetrical ERPT is strongly confirmed in most of the SSA countries with 12 cases for CFA francs Zone.

**Table 7.** Symmetry tests for the other Sub-Saharan African countries

Country	Short-run tests (W <sub>SR</sub> )	Long-run tests (W <sub>LR</sub> ):	Unrestricted & Restricted NARDL models
	$H_0: \sum_k \theta_{i,k} = \sum_k \theta_{i,k}^+$		
	$H_0: \Omega^- = \Omega^+$		
Other SSA (26)			
Angola <sup>(c)</sup>	-	5.268§	Rest. NARDL model [4]
Botswana <sup>(a)</sup>	-	12.604‡	Rest. NARDL model [4]
Cabo Verde <sup>(a)</sup>	0.000	1.578	Rest. NARDL model [5]
Comoros <sup>(a)</sup>	10.231‡	19.186‡	Unr. NARDL model [2]
Congo, Dem. Rep. <sup>(a)</sup>	89.649‡	18.103‡	Unr. NARDL model [2]
Ethiopia <sup>(a)</sup>	4.735§	2.021	Rest. NARDL model [3]
Gambia <sup>(a)</sup>	3.386†	31.198‡	Unr. NARDL model [2]
Ghana <sup>(a)</sup>	6.008§	0.201	Rest. NARDL model [3]
Guinea <sup>(a)</sup>	0.533‡	9.784‡	Unr. NARDL model [2]
Kenya <sup>(a)</sup>	1.749	55.533‡	Rest. NARDL model [4]
Lesotho <sup>(a)</sup>	6.786§	0.046	Rest. NARDL model [3]
Liberia <sup>(a)</sup>	1.336	15.238‡	Rest. NARDL model [4]
Madagascar <sup>(a)</sup>	15.562‡	10.967‡	Unr. NARDL model [2]
Malawi <sup>(b)</sup>	3.007†	-	Rest. NARDL model [3]
Mauritius <sup>(a)</sup>	0.022	52.450‡	Rest. NARDL model [4]
Mozambique <sup>(a)</sup>	5.109†	0.017	Rest. NARDL model [3]
Namibia <sup>(a)</sup>	1.117	31.412‡	Rest. NARDL model [4]
Nigeria <sup>(a)</sup>	17.208‡	482.010‡	Unr. NARDL model [2]
Rwanda <sup>(a)</sup>	8.007‡	2.303	Rest. NARDL model [3]
Sao Tome & Prin. <sup>(a)</sup>	9.692‡	0.001	Rest. NARDL model [3]
Seychelles <sup>(c)</sup>	-	97.620‡	Rest. NARDL model [4]
South Africa <sup>(a)</sup>	5.793§	23.204‡	Unr. NARDL model [2]
Swaziland <sup>(a)</sup>	-	3.777†	Rest. NARDL model [4]
Tanzania <sup>(a)</sup>	1.086	5.463§	Rest. NARDL model [4]
Uganda <sup>(c)</sup>	-	90.710‡	Rest. NARDL model [4]
Zambia <sup>(a)</sup>	1.479	4.405§	Rest. NARDL model [4]

**Note:** see Table 6

Concerning the short-term analysis, the similar *hypothesis* ( $H_4^0$ ) of symmetry does not hold (rejected) in 24 countries. Thus, we unveil many cases of both short and long-term asymmetries across the SSA countries denoting that the exchange rate movements (positive versus negative changes) do not have the same impact on domestic prices in that region except for only Cabo Verde where the symmetry hypothesis cannot be rejected neither in the short nor the long-term. As a result of these findings, the last column of Table 6 and Table 7 show the appropriate NARDL model retained to estimating the pass-through for each country. Accordingly, Table 8 and Table 9 present the results of the asymmetrical ERPT compared with those in the symmetrical specification by country.

**Table 8.** Exchange rate pass-through (ERPT) for CFA franc zone

Countries	Asymmetric exchange rate pass-through (ERPT)									Symmetric exchange rate pass-through (ERPT)					
	Long-term ERPT				Short-term ERPT			Diagnostics		Long-term ERPT		Short-term ERPT		Diagnostics	
	Adj. speed	Appr(-)	Depr(+)	LrS	Appr(-)	Depr(+)	SrS	$\overline{R}^2$	$\chi^2_{sc}$	Adj. speed	LrS	SrS	$\overline{R}^2$	$\chi^2_{sc}$	
		$\Omega_i^-$	$\Omega_i^+$	$\Omega_i$	$\sum_k \theta_{i,k}^-$	$\sum_k \theta_{i,k}^+$	$\sum_k \theta_{i,k}$				$\Omega_i$	$\sum_k \theta_{i,k}$			
<b>Waemu (Nw=8)</b>															
<i>Benin</i>	-0.072†	-0.034	0.282	-	0.347‡		0.638	0.459	-0.025	-0.711	0.131‡	0.655	0.157		
<i>Burkina Faso</i>	-0.194‡	0.251§	0.396‡	-	0.166‡		0.545	2.706†	-0.154‡	0.463‡	0.173‡	0.467	1.823		
<i>Cote d'Ivoire</i>	-0.264‡	0.207‡	0.455‡	-	-	0.184‡	0.635	0.401	-0.029	0.353	0.219‡	0.591	3.332§		
<i>Guinea-Bissau</i>	-0.118‡	-	-	0.990‡	-	-0.643‡	0.599	0.404	-0.096‡	1.151‡	-0.218§	0.548	0.905		
<i>Mali</i>	-0.322‡	0.122§	0.356‡		0.176‡	0.011	0.658	0.368	-0.061§	0.426‡	0.180‡	0.599	0.304		
<i>Niger</i>	-0.277‡	0.132	0.363‡		-	-	0.688	0.881	-0.218‡	0.699‡	0.162‡	0.650	0.243		
<i>Senegal</i>	-0.085†	-0.372	0.019		-	-	0.624	0.937	-0.038	-0.074	-0.010	0.622	1.186		
<i>Togo</i>	-0.188‡	-0.508	0.045		-	-	0.632	0.200	-0.142‡	0.641‡	0.739‡	0.585	0.759		
<b>Cemac (Nc=6)</b>															
<i>Cameroon</i>	-0.165‡	-0.474‡	0.077		-0.142‡	0.472‡	0.854	0.831	-0.036†	0.090	0.367‡	0.720	4.074		
<i>Cent. African R.</i>	0.019	-	-	-0.088	-0.200§	0.325‡	0.583	0.131	0.007	0.295	0.117‡	0.516	0.273		
<i>Chad</i>	-0.458‡	0.390‡	0.601‡		-0.249§	0.447‡	0.616	0.646	-0.290‡	0.708‡	0.260‡	0.555	0.139		
<i>Congo Rep.</i>	-0.161‡	-0.105	0.351		0.517‡	0.164‡	0.721	1.805	-0.051	0.479†	0.162‡	0.576	0.864		
<i>Eq. Guinea</i>	-0.224‡	0.035	0.518‡		-0.123	0.216‡	0.748	0.375	-0.026	0.530	0.289‡	0.580	0.897		
<i>Gabon</i>	-0.175‡	-0.070	0.317‡		-0.311‡	0.304‡	0.725	0.778	-0.097‡	0.404‡	-0.005	0.615	0.250		

Note:  $\beta_i$  is the speed of adjustment to the long-run equilibrium;  $\overline{R}^2$  is the adjusted R square and  $\chi^2_{sc}$ , the Breusch-Godfrey serial correlation LM test and the corresponding P-value in bracket. The models have been estimated following the general to specific approach with maximum lag 4.  $\sum_k \theta_{i,k}^- (\sum_k \theta_{i,k}^+)$  is the short-term additive pass-through for appreciations (depreciations) while  $\Omega^-$  and  $\Omega^+$  are their corresponding long-term pass-through coefficients. The symbols †, § and ‡ show the significance at 10%, 5% and 1% levels respectively. Authors' computations by using Eviews 9.

The hypothesis ( $H_0^2$ ) of zero long-term pass-through is rejected in 22 countries for depreciations and 17 cases for appreciations whereas the counterpart hypothesis ( $H_0^5$ ) of zero short-term ERPT cannot hold in 19 cases for depreciations against 16 cases for appreciations.

**Table 9.** Exchange rate pass-through (ERPT) in the other Sub-Saharan African countries.

Countries	Asymmetric exchange rate pass-through (ERPT)									Symmetric exchange rate pass-through (ERPT)					
	Long-term ERPT				Short-term ERPT			Diagnostics		Long-term ERPT		Short-term ERPT		Diagnostics	
	Adj. speed	Appr(-)	Depr(+)	LRS	Appr(-)	Depr(+)	SrS	$\overline{R^2}$	$\chi^2_{sc}$	Adj. speed	LRS	SrS	$\overline{R^2}$	$\chi^2_{sc}$	
		$\Omega_i^-$	$\Omega_i^+$	$\Omega_i$	$\sum_k \theta_{i,k}^-$	$\sum_k \theta_{i,k}^+$	$\sum_k \theta_{i,k}$				$\Omega_i$	$\sum_k \theta_{i,k}$			
<b>Other SSA (No=26)</b>															
Angola	-0.072‡	-4.121†	0.934‡	-	-	-	0.506‡	0.938	0.084	-0.034	0.878‡	0.562‡	0.935	0.570	
Botswana	-0.021	-0.748	-0.129	-	-	-	-	0.601	0.529	-0.015	-0.607	-	0.598	0.782	
Cabo Verde	-	-	-	-	-	-	-	-	-	-0.134‡	0.183†	0.105§	0.320	1.182	
Comoros	-0.859‡	-0.830‡	-0.356‡	-	0.272	-1.265‡	-	0.852	3.987§	-0.872‡	-0.466‡	0.913‡	0.584	0.242	
Congo, Dem. Rep	-0.207‡	-1.784‡	0.719‡	-	4.400‡	-0.089†	-	0.901	0.799	0.142†	1.075‡	1.010‡	0.781	0.766	
Ethiopia	0.144‡	-	-	0.556‡	-5.978§	-0.232‡	0.272‡	0.626	1.554	-0.133†	0.131	-0.114§	0.626	2.234	
Gambia	-0.172‡	0.038	0.399‡	-	-0.069†	-	-	0.354	1.127	-0.058‡	0.826‡	-	0.183	0.283	
Ghana	-0.056§	-	-	0.853‡	-0.573†	0.246‡	-	0.622	2.576†	-0.044	0.871‡	0.251‡	0.617	2.767†	
Guinea	0.169‡	1.703‡	2.172‡	-	0.533‡	-0.000	-	0.938	3.238†	0.032	3.597	0.193‡	0.656	2.792†	
Kenya	0.096‡	-1.556‡	0.674§	-	-	-	-	0.476	0.127	-0.009	-5.014	0.247‡	0.471	1.173	
Lesotho	-0.015	-	-	-0.887	-0.125†	0.164‡	-	0.415	0.973	-0.027§	-0.324	-	0.373	1.673	
Liberia	-0.230‡	0.771‡	1.549‡	-	-0.193‡	0.205§	-	0.645	1.362	0.033	1.634	0.425§	0.481	1.253	
Madagascar	-0.161‡	0.149	0.699‡	-	-	-	-	0.426	0.578	-0.071‡	0.806‡	-	0.410	1.067	
Malawi	-0.108‡	-	-	0.851‡	0.276	0.102‡	-	0.860	1.455	-0.077§	0.830‡	0.172	0.862	1.296	
Mauritius	-2.751‡	0.226§	0.765‡	-	-	-	-0.135‡	0.222	0.359	-0.020†	0.618	-0.121‡	0.201	0.672	
Mozambique	-0.643‡	-	-	0.747‡	0.747†	-0.558‡	-	0.932	6.233§	0.060	4.137	0.995‡	0.894	4.724§	
Namibia	-0.118†	-1.067	0.011	-	-	-	0.082	0.349	0.654	-0.013	0.642	0.047	0.082	0.265	
Nigeria	-0.235‡	-5.750‡	0.561‡	-	2.625‡	0.107‡	-	0.713	0.072	-0.021§	0.316	0.040§	0.630	0.843	
Rwanda	-0.086‡	-	-	0.655‡	-	-	-	0.264	2.114	-0.086‡	0.655‡	-	0.264	2.114	
Sao Tome and Prin	-0.126‡	-	-	1.878‡	0.379‡	-0.140	-	0.700	1.135	-0.209‡	1.983‡	-0.137	0.690	0.975	
Seychelles	-0.526‡	0.302‡	0.632‡	-	-	-	0.347‡	0.606	4.575§	-0.243‡	0.974‡	0.221‡	0.527	0.764	
South Africa	-0.050‡	0.103	0.416‡	-	-	-0.055§	-	0.536	1.121	-0.012	-0.033	0.004	0.522	0.857	
Swaziland	-0.061†	0.257	0.595‡	-	-	-	-	0.458	0.184	-0.030†	0.714‡	-	0.456	0.170	
Tanzania	-0.125‡	-1.554†	0.368	-	-	-	-0.254‡	0.546	1.892	0.014	5.901	0.438‡	0.524	1.320	
Uganda	-0.277‡	-0.801‡	0.238§	-	-	-	0.278‡	0.295	1.667	-0.040	0.888§	0.085§	0.223	4.131§	
Zambia	-0.125‡	0.547‡	0.775‡	-	-	-	0.114§	0.749	0.260	-0.065§	0.658‡	0.173‡	0.754	1.454	

Note: see Table 8

These findings reveal that not taking into account asymmetries in the relationship between exchange rates and consumer prices in the SSA region probably yield to biased conclusion with regard to the appropriate policy to be implemented.

Besides, there is positive association between changes in consumer prices and local currency depreciations contrary to appreciations in most of the SSA countries, especially in CFA francs zone (WAEMU and CEMAC) over the long-term. In fact, the positive association between depreciations and local prices is expected because the weakening of the domestic currency makes imports more expensive leading to the increase of consumer prices, all other things being unchanged. Another finding is that consumer prices react strongly and significantly to local currency depreciations than appreciations in several SSA countries over the sample period since the pass-through coefficients for appreciations are smaller than that for depreciations in absolute value ( $|\Omega^-| < |\Omega^+|$  and  $\left| \sum_i^s \theta^- \right| < \left| \sum_i^s \theta^+ \right|$ ) especially in CFA francs zone.

Furthermore, the hypotheses ( $H_0^3$ ) and ( $H_0^6$ ) of complete exchange rate pass-through (ERPT) into consumer prices are rejected in all the SSA countries except for 9 cases where the evidences of complete ERPT are only found for depreciations in Angola, and Kenya and one case for appreciation in Liberia as well as for the case of a symmetrical ERPT in Ghana and Lesotho over the long-term and only one case in the short-term for depreciation in Mozambique (the results are available upon request). Thus, 1% depreciation of Angolan Kwanza (Kz) (respectively Kenyan Shilling, KES) induces a significant increase fully transmitted to consumer prices of 0.93% (respectively of 0.67%) in Angola (respectively in Kenya) in the long-term.

However, 1% appreciation of LRD increases prices significantly by 0.77% in Liberia over the long-term. Generally, the exchange rate movements are not fully transmitted into consumer prices in most SSA countries and this can be due to some improvements in macroeconomic policies.

Additionally, the adjustment speed of consumer prices toward the long-term equilibrium prices is higher in the asymmetrical specifications (NARDL models [2], [3] and [4]) compared with the linear specification (model [5]) where the asymmetries are neglected. The pass-through coefficients are greater in the symmetrical (linear) model [5] than in the asymmetrical models [2], [3] and [4], especially during the long-term in CFA franc zone, whereas there are mixed evidences in the other SSA countries. Nevertheless, there is a positive relationship between consumer prices and exchange rate changes over time in the linear specification (model [5]), whereas this positive relationship over time cannot hold when allowing for asymmetries.

Finally, we compute the dynamic multipliers for each country to trace the patterns of the exchange rate pass-through into prices over time (see Appendix, Figure A.1 and Figure A.2). Moreover, Figure A.1 and Figure A.2 present the pattern of the dynamic multipliers respectively in CFA francs zone (Waemu and CEMAC) and the other SSA countries where the asymmetry line shows how consumer prices react differently to shocks on exchange rates during periods of depreciations and appreciations.

These figures illustrate that consumer prices respond more strongly to exchange rate depreciations than appreciations in the very short-term (after few quarters) in several SSA countries, but also the asymmetrical pass-through pattern still increases even in the very short-term and tend to zero particularly in Cabo Verde justifying the symmetrical pass-through in this country

#### 4.2. Results of the dynamic panel ERPT estimations

Hereafter, we aggregated the countries into two main subgroups: the CFA francs zone (Waemu and Cemac sub-regions) and the other SSA countries (flexible exchange rate regime) that do not belong to the CFA franc zone which has fixed exchange rate regime and almost similar currency.

##### 4.2.1. Robustness tests under cross-sectional dependence analysis

We begin the robustness tests by performing four cross-sectional dependence tests as mentioned in the methodology part i.e. the  $R_{ave}$  statistic of Friedman (1937), the  $CD_{LM}$  of Breusch and Pagan (1980), the  $FT$  statistic of Frees (1995) and the  $CD$  test of Pesaran (2004), under the null hypothesis of no autocorrelation of the residuals across panel units. Table 10 presents the results of the different tests and their corresponding P.values after running fixed and random effects estimations. The results confirm the existence of cross-sectional dependence between countries since the P.values of these tests are less than conventional significance levels (1%, 5% or 10%) and lead to rejection of the null hypothesis.

**Table 10.** Cross-sectional dependence tests

Cross dependence tests	$CD$		$FT$		$R_{ave}$		$CD_{LM}$	
	Coef	P.value	Coef	P.value	Coef	P.value	Coef	P.value
Fixed effect ( <i>Waemu</i> )	24.262	0.000	3.368	0.000	519.615	0.000	1559.421	0.000
Random effect ( <i>Waemu</i> )	24.116	0.000	3.409	0.000	528.953	0.000	1553.250	0.000
Fixed effect ( <i>Cemac</i> )	6.210	0.000	1.207	0.000	165.836	0.000	314.531	0.000
Random effect ( <i>Cemac</i> )	5.787	0.000	0.982	0.000	180.469	0.000	271.852	0.000
Fixed effect ( <i>Other countries</i> )	25.842	0.000	7.046	0.000	162.692	0.000	5647.464	0.000
Random effect ( <i>Other countries</i> )	13.113	0.000	7.704	0.000	159.692	0.000	8331.561	0.000
Fixed effect ( <i>All countries</i> )	61.443	0.000	12.345	0.000	423.375	0.000	18037.340	0.000
Random effect ( <i>All countries</i> )	29.254	0.000	9.441	0.000	186.450	0.000	23452.550	0.000

**Note :**  $CD$ ,  $FT$ ,  $R_{ave}$  and  $CD_{LM}$  are the Pesaran (2004), Frees (1995), Friedman (1937) and Breusch and Pagan (1980) test statistics respectively. Authors' calculations by using Stata 14.

##### 4.2.2. Results of Panel pass-through estimations

We perform the robustness tests through two dynamic panel models accounting for by cross-sectional dependence, autocorrelations and heteroskedasticity: the Feasible Generalized Least Squares (FGLS) of Parks (1967) and the Pooled OLS regression using robust standard errors of Driscoll and Kraay (1998). The two estimators have been employed for checking whether our findings are still robust and the results are depicted in Table 11.

We still find that the hypotheses ( $H_0^1$ ) and ( $H_0^4$ ) of a symmetrical ERPT over short and long-term are rejected in the CFA francs zone (Waemu and Cemac sub-regions) while this is not the case for the other SSA countries and the entire SSA region over the long-term according to the Pooled OLS regression using robust standard errors of Driscoll and Kraay (1998). Accordingly, the FGLS and the

Pooled OLS estimators both provide evidence of an asymmetrical behavior of exchange rates into consumer prices in all sub-regions as well as in the entire SSA region over the short-term. Besides, these two estimators validate our findings of non-zero pass-through for depreciations and appreciations (rejection of *hypothesis 2 and 5*) as well as in the linear ARDL model [5] over the short and long-term. Moreover, the results of the panel analysis reject the *hypothesis* ( $H_0^3$ ) and ( $H_0^6$ ) of a complete ERPT for appreciations and depreciations, respectively over long and short-terms, except for Cemac sub-region where both FGLS and Pooled OLS estimators reveal a complete ERPT for local currency depreciations and appreciations in the long-term (results are available upon request).

**Table 11.** Panel ERPT estimation under cross-sectional dependence analysis

Country	Long-term Relationship						Short-term Relationship			
			Long-run ERPT			Wald test	Cumulative ERPT			Wald test cumulative
	Asym.	Sym.					Appr(-)	Depr(+)	SR <sub>ERPT</sub>	
	Adjust. Speed, $\beta_i$	Adjust. Speed, $\psi_i$	Appr(-): $\Omega_i^-$	Depr(+): $\Omega_i^+$	LR <sub>ERPT</sub> $\Omega_i$	Long-run $H_0 : \Omega^- = \Omega^+$	$\sum_k \theta_{i,k}^-$	$\sum_k \theta_{i,k}^+$	$\sum_k \theta_{i,k}$	$H_0 : \sum_k \theta_{i,k}^- = \sum_k \theta_{i,k}^+$
FGLS estimator										
CFA Franc zone (N=14)	-0.049‡	-0.046‡	0.447‡	0.637‡	0.648‡	16.530‡	-0.118‡	0.265‡	0.183‡	106.530‡
<i>Waemu</i> ( $N_w=08$ )	-0.064‡	-0.058‡	0.387‡	0.544‡	0.563‡	11.410‡	-0.115‡	0.258‡	0.177‡	60.240‡
<i>Cemac</i> ( $N_c=06$ )	-0.033‡	-0.032‡	0.574§	0.845‡	0.839‡	4.860§	-0.130‡	0.277‡	0.187‡	46.840‡
Other SSA (N=26)	-0.016‡	-0.016‡	0.410‡	0.195‡	0.032§	8.290‡	-0.012	0.118‡	0.087‡	29.350‡
All SSA countries (N=40)	-0.015‡	-0.015‡	0.420‡	0.244‡	0.011	9.570‡	-0.030§	0.176‡	0.127‡	114.440‡
POLS_DK estimator										
CFA Franc zone (N=14)	-0.050‡	-0.049‡	0.438§	0.640‡	0.673‡	6.290§	-0.091	0.244‡	0.175‡	10.220‡
<i>Waemu</i> ( $N_w=08$ )	-0.057‡	-0.056‡	0.401§	0.553‡	0.581‡	3.480‡	-0.058	0.222‡	0.165‡	6.040§
<i>Cemac</i> ( $N_c=06$ )	-0.038‡	-0.036‡	0.552‡	0.858‡	0.878‡	5.040§	-0.147§	0.283‡	0.193‡	16280‡
Other SSA (N=26)	-0.020‡	-0.018‡	0.181	0.125‡	0.040‡	0.270	0.105	0.196‡	0.187‡	1.520
All SSA countries (N=40)	-0.020‡	-0.019‡	0.174‡	0.140‡	0.027	0.130	0.057	0.210‡	0.191‡	7.460‡

**Note:** FGLS stands for Feasible Generalized Least Squares; *POLS\_DK* denotes Pooled OLS (Ordinary Least Squares) estimator using Driscoll-Kraay standard errors which are robust to heteroskedasticity, autocorrelation and cross-sectional dependence of errors up to lag 4 between panel units. The statistics for wald tests are Chi2(1) values. The symbols †, § and ‡ show the significance at 10%, 5% and 1% levels respectively. Authors' calculations by using Stata 14.

These estimators induce more accurate, consistent estimates and validate the finding that exchange rate are strongly passed through prices during depreciations than appreciations, especially in CFA franc zone in long-term. However, the evidence that consumer prices react more strongly to local currency depreciations than appreciations is largely valid across sub-regions as well as in the entire SSA region during the short term. Therefore, our results of asymmetric exchange rate pass-through (ERPT) are more robust during the short and long-terms for the global CFA franc zone while these findings are significantly appropriate in the short-term for the other SSA countries as well as the entire SSA region.

However, the evidence of incomplete ERPT is robust for in the SSA countries over the short and long-term. In addition, consumer prices are negatively associated to local currency appreciations but

positively linked to depreciations over the short-term, whereas both have positive effect and different impacts on consumer prices in long-term. For instance, both FGLS and Pooled OLS estimates reveal that 10% depreciation of exchange rate leads to about 6% increase in consumer prices in CFA franc zone while the same percentage causes prices to raise by 4% or so following appreciations in the long-term, with different magnitudes across Waemu and Cemac sub-regions. In the other SSA countries and the entire SSA region, 10% depreciations (appreciations) increase prices level approximately by 2% over the long-term. Nevertheless, local prices approximately decrease by 1% (respectively about 0.1% in the other SSA countries and around 0.3% in the SSA region) for 10% appreciations of the exchange rate in CFA franc zone according to FGLS whereas 10% depreciation of the local currency raises consumer prices above 2% (less than 2% for the other SSA economies, as well as the global SSA region) during the short-term.

In short, the evidence of an asymmetrical exchange rate pass-through in most of the SSA countries nourishes the thought that producers may not distinguish the diverse effects of the local currency depreciations and appreciations on domestic prices or they could be unable or reluctant to take these effects into consideration in their operating margins over the short-term. This situation may also encourage the alternative of speculation in the short-term since local currency depreciations and appreciations do not have the same impact on consumer prices. Besides, the strong pass-through elasticities for depreciations than those of appreciations reveal that foreign producers are prone to raise prices in most SSA countries for limiting the decrease of their profits, which is to partially pass local currency depreciations into consumer prices while keeping constant prices and raising their markups by the absorption of appreciations and quote for competitive prices.

Our findings unveil the lack of competitive market structures in the SSA region denoting by this kind of high pricing power since foreign producers have large market share in this region. For instance, the shares of European and Asian exports in world merchandise exports to Africa region are about 34.7% and 32.4% respectively while only 15.4% come from Africa in 2014.<sup>1</sup>

Furthermore, we find that the exchange rate pass-through is high in CFA franc region having a relatively low inflationary environment, measured by the average inflation rate (1.04%) compared with the other SSA countries (3.13%) associated to high inflation levels (see Table 11). This evidence contrasts the Taylor (2000) hypothesis that lower EPRT is positively associated with low inflationary environment which reduces the pricing power of producers. In fact, the FGLS of Parks (1967) and the Pooled OLS regression with standard errors of Driscoll and Kraay (1998) have corrected any bias resulting from the presence of cross-sectional dependence between countries.

Thus, this result points out the lack or limited credibility of monetary policy in the SSA region, the frail transmission of its monetary policy associated with a lower financial depth paining to adapt to exchange rate shocks. Hence, producers tend to pass-through exchange rate changes when inflation expectations are not well anchored on a target, which can be interpreted as a lack of transparency in the monetary policy, hindering the decline in the exchange rate pass-through into consumer prices.

In general, the results of this paper are opposed to the findings of Akofio-Sowah (2009) exhibiting a declining and symmetric pass-through elasticities in 15 SSA countries under lower inflationary environment. However, our findings are similar to those reported in the IMF's working papers (Razafimahefa, 2012) in the sense of incomplete pass-through into consumer prices which is larger during exchange rate depreciations than appreciations.

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<sup>1</sup>World Trade Organization, International Trade Statistics 2015.

#### 4.2.3. Estimations of the pass-through with respect to the size and direction of exchange rates.

In this section, we decompose exchange rate movements into large and small changes in order to examine the impact of these changes in consumer prices. In order words, we investigate whether menu costs are important in the SSA countries i.e. whether the size of pass-through is positively related to the size of the exchange rate. Thus, we employ the approach of Pollard and Coughlin (2004) to construct large changes of exchange rates.

To do so, we distinguish large changes to small changes of exchange rate following Pollard and Coughlin (2004) in this manner:

$$L_t = 1 \text{ if } |\Delta l e r_t| \geq 3\%, \quad L_t = 0 \text{ , otherwise and } S_t = 1 \text{ if } |\Delta l e r_t| < 3\%, \quad S_t = 0 \text{ , otherwise}$$

We use these dummy variables to construct large changes ( $L_t \Delta l e r_t$ ) and small changes ( $S_t \Delta l e r_t$ ) of exchange rates.

**Table 12.** Behavior of the exchange rate

Behavior of the exchange rate: 1990Q1-2017Q4							
(Percent of total changes)							
Sub-regions	Overall		Appreciations		Depreciations		
	Large	Small	Large	Small	Large	Small	
	Change	Change	Change	Change	Change	Change	
CFA Franc zone (N=14)	58.63	41.37	29.18	70.82	28.85	71.15	
Waemu (Nw=08)	58.41	41.59	29.82	70.18	29.01	70.99	
Cemac (Nc=06)	58.93	41.07	28.33	71.67	28.64	71.36	
Other SSA (No=26)	45.10	54.90	13.42	86.58	30.15	69.85	
All SSA countries (N=40)	50.27	49.73	19.37	80.63	29.63	70.37	

**Note:** Authors' calculation

Then, we estimate the NARDL model [2] and [5] using these variables instead of  $\Delta l e r_t$  and allowing both the linear and nonlinear specifications. Table 12 describes the size of the exchange rate across sub-regions as well as in the entire SSA region.

The statistics reveal that there have been large exchange rate changes in CFA francs zone (58.63%) than in the other SSA countries (45.10%) following the linear specification. Considering the direction of the exchange rate, we note a longer period of small changes than large changes in exchange rate across sub-regions. Moreover, the results of the implied ERPT are presented in Table 13. First, the results suggest asymmetrical ERPT with regard to the size of the exchange rate where the pass-through is higher after large changes in the exchange rate than small changes.

Second, the ERPT is greater during large depreciations than large appreciations of the local currency. Consumer prices decrease at a high level after large depreciations (positive exchange rate changes) than they increase during the appreciations (negative exchange rate changes) of the local currency.

**Table 13.** Pass-through with respect to exchange rate's direction and size

Sub-regions	Overall			Appreciations			Depreciations			Asymmetry tests	
	Large	Small	H <sub>0</sub> :	Large	Small	H <sub>0</sub> :	Large	Small	H <sub>0</sub> :	H <sub>0</sub> :	H <sub>0</sub> :
	L	S	L = S	LA	SA	LA = SA	LD	SD	LD = SD	LA = LD	SA = SD
<i>FGLS estimator</i>											
CFA Franc zone (N=14)	0.102‡	-0.047	5.740§	-0.127‡	-0.344‡	4.460§	0.170‡	0.228§	0.380	120.060‡	11.750‡
<i>Waemu</i> (N <sub>w</sub> =08)	0.101‡	-0.061	4.050§	-0.125‡	-0.289§	1.500	0.169‡	0.150	0.020	68.720‡	4.100§
<i>Cemac</i> (N <sub>c</sub> =06)	0.099‡	-0.029	1.780	-0.128‡	-0.415§	3.240†	0.166‡	0.330§	1.220	49.670‡	8.230‡
Other SSA (N <sub>o</sub> =26)	0.008†	0.017	0.040	-0.026	-0.089	0.500	0.064‡	-0.009	1.040	14.740‡	0.340
All SSA countries (N=40)	0.067‡	-0.043	8.590‡	-0.055‡	-0.214‡	6.010§	0.112‡	0.124§	0.040	96.710‡	11.270‡
<i>POLS_DK estimator</i>											
CFA Franc zone (N=14)	0.102†	0.012	0.810	-0.157‡	-0.203	0.090	0.173‡	0.264	0.330	16.130‡	2.750†
<i>Waemu</i> (N <sub>w</sub> =08)	0.101†	0.027	0.390	-0.142§	-0.062	0.170	0.167‡	0.165	0.000	13.510‡	0.410
<i>Cemac</i> (N <sub>c</sub> =06)	0.101	-0.010	1.270	-0.169‡	-0.359§	1.530	0.177‡	0.366§	1.510	14.870‡	7.400‡
Other SSA (N <sub>o</sub> =26)	0.101‡	-0.155	5.580§	-0.045	0.062	0.50	0.291‡	0.037	2.530	20.750‡	0.010
All SSA countries (N=40)	0.226‡	0.041	4.370§	-0.060†	0.002	0.320	0.269‡	0.170	0.830	34.160‡	0.600

**Note:** FGLS stands for Feasible Generalized Least Squares; *POLS\_DK* denotes Pooled OLS (Ordinary Least Squares) estimator using Driscoll-Kraay standard errors which are robust to heteroskedasticity, autocorrelation and cross-sectional dependence of errors up to lag 4 between panel units. The statistics for wald tests are Chi2(1) values. The symbols †, § and ‡ show the significance at 10%, 5% and 1% levels respectively. Authors' calculations by using Stata 14.

## 5. Conclusion

This paper investigated the relationship between exchange rate movements and consumer price index in 40 Sub-Saharan African (SSA) countries from 1990q1 to 2017q4 by employing the nonlinear autoregressive distributed lags (NARDL) approach as well as dynamic panel estimators under cross-sectional dependence analysis. First, the results suggested that there was an asymmetrical exchange rate pass-through (ERPT) in most of the SSA countries generally in the short-term, except for CFA franc sub-region (Waemu and Cemac sub-regions) where asymmetry occurred both in short and long-terms. Second, the hypothesis of zero pass-through did not hold in many SSA countries, as well as the hypothesis of complete ERPT in the short and long-term. Thus, consumer prices reacted strongly to local currency depreciations than appreciations in the short and long-terms, which is in line with the result of Razafimahefa (2012) and the capacity constraints model of Knetter (1994) suggesting the existence of trade barriers in the SSA region. This reflects downward prices rigidities and weak market competition in many SSA countries. Indeed, the downward price rigidity arises from the fact that foreign producers may not be able to contain huge demand emanating from an appreciation of the importer's currency. Thus, they tend to absorb appreciations by increasing their markup and keep price fixed. This situation occurs in the case where producers or domestic firms are binding by quantity constraints such as quotas, trade restrictions, anything that prevent them to

expand their productions. A situation that leads to weak competitive market in which foreign producers can only widen its profit margins rather than increasing sales. In this scenario, the pass-through will be greater during the depreciation of importer's currency. Third, we found that the exchange rate pass-through into prices has not declined after the 1990s, especially over the long-term in the CFA franc zone. It was higher in CFA franc zone (fixed exchange rate regime) having low price levels (1.04%) compared with the other SSA countries (flexible exchange rate regime) associated to high average inflation level (3.13%) when the analysis allowed for cross-sectional dependence between panel units. The ERPT coefficients differed from the SSA countries to the developing and emerging Asian countries. The ERPT in the SSA countries was low than that in emerging Asian countries in the long-term (see Kassi et al.2018).

This evidence contrasts the Taylor (2000)'s hypothesis and the results of Akofio-Sowah (2009) in the SSA region, revealing that neglecting the asymmetry assumption and cross-sectional dependence in such an analysis of ERPT may lead to biased conclusions. Nevertheless we give support to the idea of Goldberg and Campa (2010) that the increasing share of imported inputs since 1990s into local production process contributes to extend the sensibility of consumer prices to exchange rate changes. Four, we found an asymmetrical ERPT with regard to the size of the exchange rate. The ERPT was greater during large depreciations of the local currency than after large appreciations, whereas the ERPT for small appreciations was higher than that for small depreciations. Our findings unveil the lack of credibility of the monetary policy in the SSA region since inflation expectations are not well anchored on a target, reflecting a low transparency in the monetary policy which may impede a declining exchange rate pass-through into consumer prices. Hence, our contribution to the ERPT's literature in the SSA region is threefold: we extended the analysis to 40 SSA countries by using both per country and dynamic panel analysis allowing for asymmetry. Second, we considered the cross-sectional dependence analysis between countries in the estimation of ERPT. Third, our analysis took into account nonlinearity by examining the pass-through with regard to the size of the exchange rate. Our findings also raise concerns about probably speculative behavior from producers having great market power to make use of the asymmetric exchange rate pass through, profiting from weak competitive market structures in the SSA region. Such behavior can lessen consumer welfare in the destination market following the response of local prices and thereby may hinder the monetary policy of inflation targeting and export competitiveness.

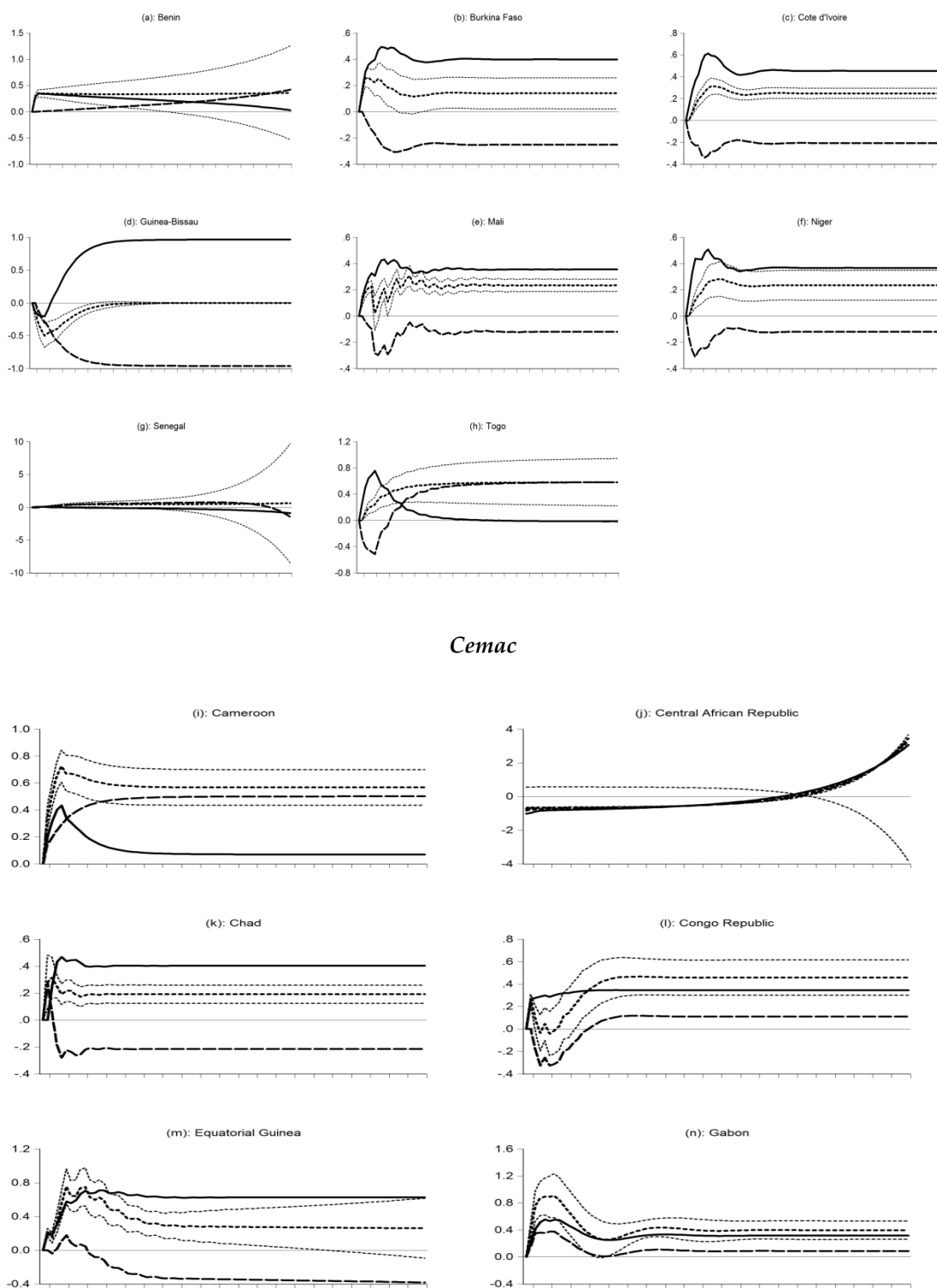
Finally, the ERPT was low under the flexible exchange rate regime relatively to the fixed regime. Hence, the SSA countries should not be "fear of floating" as they can benefit from trade liberalization. Therefore, the policy implication is to take into account these asymmetrical effects of exchange rates on consumer prices in determining the monetary policy rules, to promote trade liberalization and enhance macroeconomic policies for more competitive market structures in Sub-Saharan African countries.

## Appendix A

**Table A1:** The critical values of Narayan (2005)

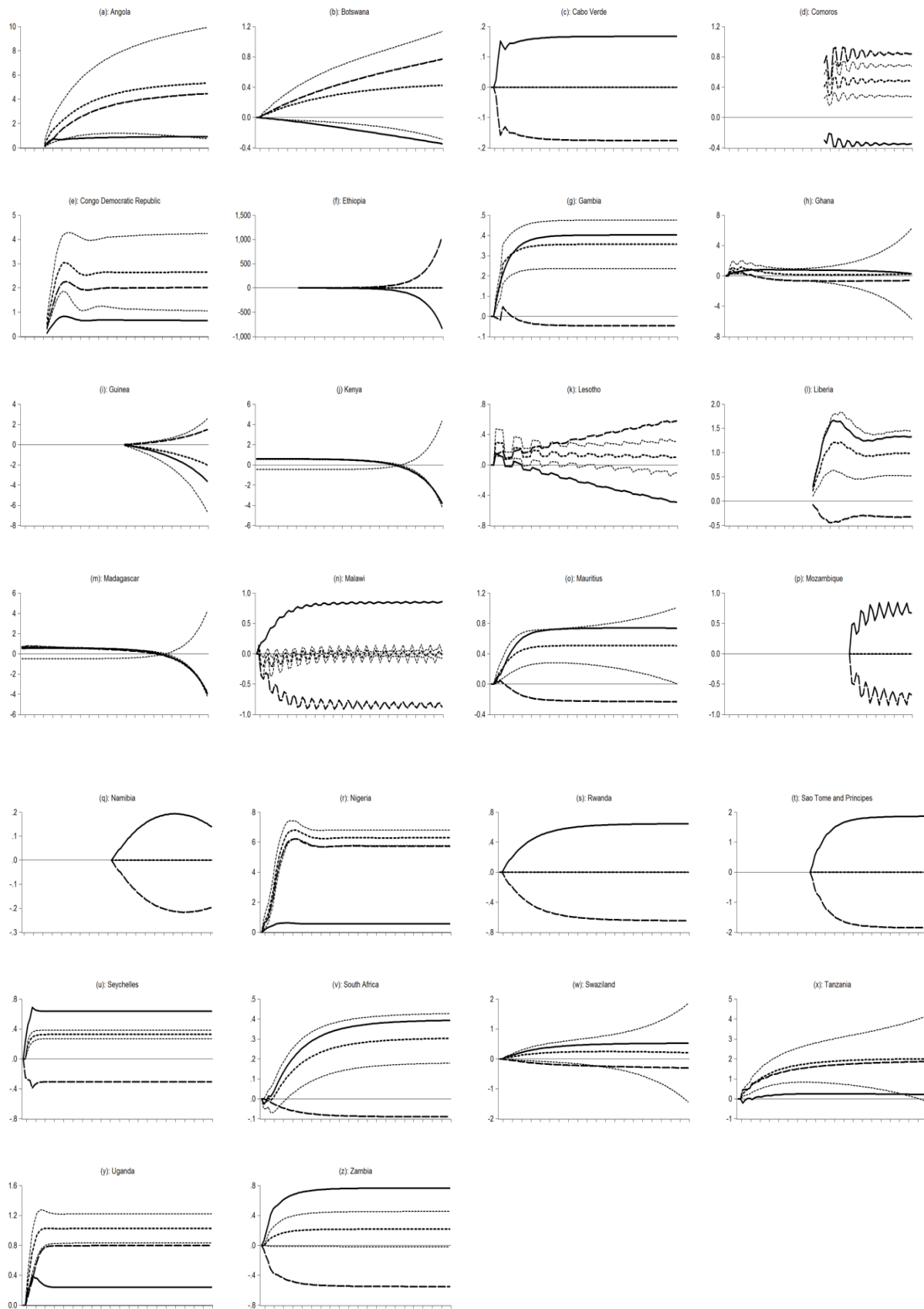
	Obs.	40	45	50	55	60	65	70	75	80	
1%	k=4	I(0)	4.428	4.394	4.306	4.244	4.176	4.188	4.098	4.168	4.096
		I(1)	6.250	5.914	5.874	5.726	5.676	5.694	5.570	5.548	5.512
	k=5	I(0)	4.045	4.030	3.955	3.928	3.783	3.783	3.747	3.772	3.725
		I(1)	5.898	5.598	5.583	5.408	5.338	5.300	5.285	5.213	5.163
5%	k=4	I(0)	3.202	3.178	3.136	3.068	3.062	3.068	3.022	3.042	3.010
		I(1)	4.544	4.450	4.416	4.334	4.314	4.274	4.256	4.244	4.216
	k=5	I(0)	2.962	2.922	2.900	2.848	2.817	2.835	2.788	2.802	2.787
		I(1)	4.338	4.268	4.218	4.160	4.097	4.090	4.073	4.065	4.015
10%	k=4	I(0)	2.660	2.638	2.614	2.578	2.568	2.574	2.552	2.558	2.548
		I(1)	3.838	3.772	3.746	3.710	3.712	3.682	3.648	3.654	3.644
	k=5	I(0)	2.483	2.458	2.435	2.393	2.385	2.397	2.363	2.380	2.355
		I(1)	3.708	3.647	3.600	3.583	3.565	3.543	3.510	3.515	3.500

**Note:** The critical values have been extracted from Narayan (2005). Obs. denotes the number of observations. k. is the number of independent variables. I(0) and I(1) represent the order of integration.



**Figure A.1. Cumulative dynamic multipliers for CFA franc zone**

Note: The dynamic multipliers have been generated by the authors using Eviews 9. The long-dashed (solid) line depicts the effect of 1% appreciation (depreciation) of the local currency i.e. negative changes (positive changes) of exchange rate on consumer prices, respectively. The asymmetry line, difference between depreciations and appreciations, is described by the short-dashed line. The horizontal and vertical lines show the time horizon and the magnitude of the pass through respectively.



**Figure A.2.** Cumulative dynamic multipliers for the other SSA countries

**Note:** see note Figure A.1

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