A panel Smooth Transition Regression Estimation of Nonlinear Exchange rate pass-through in Sub-Saharan Africa

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Abstract
This paper examines the potential nonlinearity and asymmetric exchange rate pass-through in Sub-Saharan Africa (SSA) countries. The role of nonlinearities and asymmetric exchange rate pass-through (ERPT) is examined. A panel data of 8 Sub-Saharan Africa (SSA) countries was examined from 2000Q1 to 2019Q4 applying a panel smooth transition regressive (PSTR) technique that is consistent in the presence of heterogeneity and cross-sectional dependence, which allows the regression coefficients to vary both across individual countries and over time. The results rejected the hypothesis of linearity against PSTR ERPT in the SSA countries. However, the estimation result of the PSTR fails to show a significant coefficient for the parameters both in the linear and nonlinear parts of the estimation, even though the estimated standard deviation shows that the PSTR model is more efficient. The Panel regression estimation with fixed effect indicates that the exchange rate and export cost significantly impact the import price. This result echoes the downward price rigidities in the SSA countries.

Keywords: *Exchange rate, Nonlinearity, Panel Smooth Transition Regression*
JEL: *C23, F31, G15*

1. Introduction

This paper examines the impact of nonlinearities and asymmetries in exchange rate pass-through (ERPT) on domestic prices in Sub-Saharan Africa (SSA) countries. To date, few studies have examined the impact of nonlinearities and asymmetries in the pass-through of changes in the exchange rate to domestic prices in emerging markets, particularly in SSA countries. Bussi`ere (2013) examined the presence of non-linearities and concentrations on export and import prices and found evidence of both asymmetries for the G7 economies. His study of nonlinearities and asymmetries, although magnitude differs among the countries. Frankel et al. (2012) found a threshold effect for large devaluations. They witnessed a proportionately larger pass-through effect with depreciations above 25 %. They also discover evidence of asymmetries as they cannot reject the hypothesis that appreciations are not passed through, signifying downward price rigidity. In contrast, Carranza et al. (2009) found that, in dollarised economies, due to balance sheet effects, a significant real depreciation can counterbalance the positive competitiveness and imported inflation effects through a dramatic drop in aggregate investments. Burstein et al. (2005) examine the inflation trend after nine large contractionary devaluations post-1990. They detect that the level of inflation is relatively low compared to the extent of the devaluation. They claim that the pattern is due to distribution costs and import substitution. These are some economic explanations for non-linearities during severe appreciation /depreciation.

Correctly understanding the effect of exchange rate changes on domestic prices in emerging economies is vital for policymakers. Most emerging economies significantly changed their monetary frameworks and exchange rate regimes during the past few decades. Most countries hitherto having fixed/Pegged exchange rate regimes switched to the more flexible exchange rate. The flexible exchange rate regimes lead to a different level of ERPT in the economies. It is, therefore, crucial to know how exchange rate changes affect domestic prices under flexible regimes. Furthermore, the level of ERPT directly influences the efficacy of monetary policy under flexible exchange rates and, hence, the effectiveness of the expenditure-switching mechanism.

The only study that examined the asymmetric ERPT using SSA data we came across is Kasisi *et al.* (2019), which examined the asymmetric relationship between exchange rates and consumer prices in 40 SSA countries from 1990Q1 to 2017Q4. They estimated each country's ERPT to consumer prices using the nonlinear autoregressive distributed lag (NARDL) framework. However, their study examined ERPT to consumer price against this paper, which looks at ERPT to import price using the Panel smooth transition regression (PSTR) model. This study, therefore, aims to add to the nonlinear ERPT literature by using a different model.

The rest of the paper is organised as follows: Section 2 reviews the relevant theoretical and empirical literature, which discusses potential theoretical channels for non-linearities and asymmetries and empirical studies confirming them. Section 3 describes the data and specifies the empirical model. Section 4 presents and discusses the empirical estimation result. Section 5 is the conclusion and policy implications.

2. Literature Review

2.1. Theoretical Literature Review

ERPT is often presumed linear and symmetric in the literature; however, some microeconomic factors could create size and directional asymmetries. The asymmetric ERPT is highlighted in the microeconomic framework of pricing to market theory by maintaining that foreign firms are prone to alter their markups in the importing country in response to changes in the exchange rate (Dornbusch, 1985). This possible asymmetric ERPT is mainly described in the market-share hypothesis, where the foreign exporters use to transfer the appreciation of the importer's currency to boost their market share but absorb the depreciation to sustain their profits (Marston, 1990). Therefore, ERPT will be higher when the importer's currency is appreciated than depreciated. On the contrary, the capacity constraints hypothesis suggests that foreign firms are motivated to transfer depreciation of the importer's currency and absorb appreciation since they operate at total capacity and cannot contain massive demand when the importer's currency appreciates (Knetter, 1994).

Some more recent studies (Pollard & Coughlin, 2004; Berman *et al.*, 2012; Bussi`ere, 2013) suggested the existence of asymmetries (that is, depreciation could cause a different price response compared to appreciations) and non-linearities (that is, significant exchange rate changes could lead to a non-proportional impact than small exchange rate changes). Pollard and Coughlin (2004) show that asymmetric ERPT could occur due to the pricing strategy of a foreign firm while responding to the size of the change in the exchange rate. Their hypothesis suggests that foreign exporters price their goods in their currency and, as such, would have less reason to alter prices after minor changes in the exchange rate. This strategy is called producer currency pricing (PCP), which leads to a complete ERPT. In contrast, prices are not reactive to slight exchange rate changes when exporters price their goods in the importer's currency, known as the local currency pricing (LCP) strategy. There is zero ERPT, which may only increase when prices adjust to significant exchange rate changes.

Berman et al. (2012) also show that the way the exporting firms respond to the different levels of exchange rate changes depends on the quality of the goods they export. Berman et al. (2012) show that high-quality goods have higher markups, suggesting that the price sensitivity to changes in the exchange rate is higher for high-quality goods. This microeconomic structure could also create non-linearities in the reaction of import prices to significant depreciation. Likewise, a significant depreciation to the importer is a significant appreciation to the exporter. Confronted with a large change in the exchange rate, exporters with low-quality goods will leave the market high-quality goods exporters alone in the export market. The high-quality goods exporters can then absorb the changes in the exchange rate in their mark-ups, which will result in lesser pass-through to the import price. This will cause a lesser pass-through for significant depreciation to the importer price. On the other hand, when the exporter market is full of exporters with small markups, they cannot absorb the significant appreciation, hence transferring most of the change in the exchange rate to the price. In a nutshell, the quality of the imported goods and the exporters' markups create ERPT non-linearities.

Similarly, Bussi`ere (2013) highlighted various channels that could cause asymmetries and non-linearities. Bussi`ere (2013) suggested that export prices are typically downward rigid, making it easier for exporters to increase markup than decrease it. This indicates that with depreciation in the exchange rate, exporters can raise their export prices more than they would decrease them with an appreciation. This implies that depreciation would significantly impact import prices more than appreciation. It is important to reflect about depreciation on the import as an appreciation on the export, as such exporters facing exchange rate appreciation are constrained by downward price rigidity and can only absorb a portion of the change in the exchange rate in their markup, which means more significant pass-through to the importers. This hypothesis also means possible non-linearities with the elasticity of prices to exchange rate changes. Where exporters face a significant appreciation, altering their markup will be even more challenging, which can lead to a more significant pass-through for the importers.

Likewise, another source of nonlinearities and asymmetries is the upward rigidity of export quantities. Exporters facing depreciation and operating at full capacity cannot increase their sales by raising their production capacities. Hence, they could respond by raising their markup instead of increasing their capacity, leading to a lesser pass-through for the importer.

In a comprehensive literature review of ERPT in developing economies, Aron et al. (2014) analysed these nonlinear and asymmetric ERPT channels. However, only a few studies examined the channels, particularly for developing countries.

2.2. Empirical Literature Review

Most early ERPT studies assumed linear and symmetrical ERPT (ERPT) to import prices. Particularly the studies that used data from advanced countries (See Taylor, 2000; Campa & Goldberg, 2005). Taylor (2000) suggested a declining ERPT during a low inflationary regime in the 1990s, using data from 14 advanced countries. This proposition was confirmed by many other works (Choudhry et al., 2005; Frankel et al., 2011). Most empirical studies concluded that the ERPT was incomplete and smaller in advanced countries than in emerging economies. (See Goldberg and Knetter 1996; Bussière et al. 2014).

Another turn to the research on the ERPT is the issue of nonlinear and asymmetric pass-through of the change in exchange rates to prices (see Delatte and Lòpez-Villavicencio 2012; Bussière et al., 2014; Brun-Aguerre et al., 2016; Baharumshah et al., 2017; Kassi et al., 2018). For this area of research, those in SSA countries are very limited.

Brun-Aguerre et al. (2016) examined the ERPT to import prices using panel data of 14 developing countries and 19 advanced countries from 1980Q1 to 2010Q4. The study used the nonlinear autoregressive distributed lag (NARDL). The results discovered asymmetric ERPT whereby higher pass-throughs observe exchange rate depreciations than appreciations in the long term.

Likewise, Kassi et al. (2018) also reported an asymmetric ERPT for a study on developing and emerging Asian economies using quarterly data from 1995Q1 to 2016Q4. The study also used the NARDL framework and found asymmetry in ERPT.

There have been few studies on ERPT in Sub-Saharan African countries, primarily individual country studies. Razafimahefa (2012) examined 34 SSA countries, comprising 23 fixed and 11 flexible regimes countries. The study investigated ERPT and the factors determining it using quarterly data from 1985 to 2008. The study reported incomplete ERPT and higher exchange rate depreciations than appreciations. Maka (2013) studied the asymmetric ERPT to inflation in Ghana, applying a structural VAR model using monthly data from 1990 to 2011. Maka (2013) also reported asymmetric ERPT, which is higher with depreciations than appreciations.

Similarly, Jooste and Jhaveri (2014) studied the ERPT in South Africa and reported declining ERPT during a low inflationary period. The study also showed a higher ERPT during volatile exchange rates. Most ERPT studies in the SSA are single-country studies, and only very few consider the potential nonlinear and asymmetric ERPT. Therefore, this study aims to fill this gap in the ERPT literature in the SSA add to the literature by examining the nonlinearity and asymmetry in the ERPT using the panel model and considering cross-sectional dependencies.

3. Data and model specification

The study used panel data from 8 SSA countries. The study covers a period from 1990 to 2019. The data are derived from the Penn World Table (Feenstra *et al*., 2015) and the World Bank's World Development Indicators (WDI) database. The 8 SSA countries in the sample are Gabon, Ghana, Gambia, Lesotho, Malawi, Nigeria, Uganda, and South Africa. The countries are chosen based on the availability of the required data. We also considered countries with exchange rate regimes that are either floating or managed floating, which allow for changes in the exchange rate. The data set includes five variables that are presented in Table 1.

Table 1: Variable description and sources

Variables	Description	Source
mp	Import price	Penn World Table, version 10
er	Exchange rate.	Penn World Table, version 10
y	Demand conditions in the importing country are proxied by real GDP.	Penn World Table, version 10
w	Exporting countries' costs are proxied by Exporting countries' wages.	Computed using data from International Financial Statistics (IFS) of the IMF.

The variables import price (**mp**), the exchange rate (**er**), and the real GDP (**y**) are derived from the Penn World Table, version 10 (Feenstra et al., 2015). Meanwhile, the exporting countries' wage(**w**) was computed using IMF's International Financial Statistics (IFS) data.

The import price (**mp**) is calculated based on the price level of the USA GDP in 2017 = 1. The exchange rate (**er**) is a national currency per USD (market + estimated). The real GDP (**y**) representing the demand conditions in the importing country is a real GDP at constant 2017 national prices (in mil. 2017 US$). The data for wages in the exporting country is not directly obtainable. We, therefore, constructed a proxy for the **w** following Bailliu and Fujii (2004). The real effective exchange rate (REER) based on unit labour costs is used to create a trade-weighted measure of foreign producers' costs. See Appendix 1 for the descriptive statistics of the variables.

We use the PSTR model Gonzalez et al. (2005) developed to detect the potential non-linear relationship between exchange rate and import price. To show the nonlinear ERPT to the import price, the study estimates a Panel smooth transition regression (PSTR) model describing the ERPT with threshold and a transition function as follows:

$$y_{it} = \mu_i + \beta_0 x_{it} + \beta_1' x_{it}\, g(lner, \gamma, c) + \varepsilon_{it} \quad (1)$$

Where y_{it} is a scalar dependent variable, x_{it} is a k-dimensional vector of time-varying control variables. Transition function $g(lner, \gamma, c)$ is a continuous function. It depends on threshold variable ($lner$) and to be bounded between 0 and 1. These extreme values are associated with regression coefficients β_0 and (β_0 + β_1). While the subscript i = 1. . ..N, and t = 1. . ...T; N and T represent the cross-section and time dimensions of the panel, respectively; μ_i represents the fixed individual effect and ε_{it} is the errors.

Gonzalez *et al.* (2005) followed Granger *et al.*'s (1993) time series STAR models, which follow logistic transition function:

$$g(lner, \gamma, c) = \left(1 - exp\left(-\gamma \prod_{j=1}^{m} (lner_{it} - c)\right)\right)^{-1} \quad (2)$$

with $\gamma > 0$ **and** $c_1 \leq c_2 \leq \cdots c_m$

Where $c_j = c_1 \dots c_m$, vector of parameters with m dimension; the slope parameter depicts the smoothness of the transition. When m = 1, the model would have the two extreme regimes separating low and high values of $lner_{it}$ with a single monotonic transition of the coefficients from β_0 to (β_0 + β_1). as $lner_{it}$ rises. With a higher value, the transition becomes rougher and transition function $g(lner, \gamma, c)$ becomes the indicator function $g(lner, c)$. When tends towards infinite, indicator function $g(lner,, c) = 1$ if event $lnepu > c$ occurs, and indicator function $g(lner, c) = 1$ otherwise. When is close to 0, the transition function $g(lner, \gamma, c)$ is constant. In that case, the PSTR converges towards the two-regime panel threshold regression (PTR) of Hansen (1999). In general, for any value of m, the transition function $g(lner, \gamma, c)$ is constant when is close to 0. In which case, the model in equation (1) becomes a linear panel regression model with fixed effects.

The empirical model to be estimated is presented as follow:

$$lnmp_{it} = \mu_i + \beta_1^0 lner_{it} + \beta_2^0 lny_{it} + \beta_3^0 lnw_{it} + [\beta_1^1 lner_{it} + \beta_2^1 lny_{it} + \beta_3^1 lnw_{it}]\, g(lner, \gamma, c) + \varepsilon_{it} \quad (3)$$

The prefix ln to all the defined variables denoted the logarithm expression of the variables. The econometric method follows four steps: first, we carried out a cross-section dependency test to ascertain whether there is a correlation between the variable in the panel data to be guided as to the type of unit root test to be used. Secondly, the stationarity test is carried out on each variable using unit roots tests that include cross-sectional independence and cross-sectional dependence. Thirdly, a linearity test against the PSTR model and the transition functions is carried out. Then fourthly, the non-linear least-squares methods will be used to estimate the PSTR model. Finally, a robustness check of the PSTR estimates will be conducted.

4. Model estimation and results

4.1Preliminary test

We carry out a preliminary test for cross-sectional dependences and unit root tests using the second-generation panel unit root tests.

4.1.1 Testing for cross-sectional dependence

We start the analysis by determining the level and the source of cross-sectional dependence among the variables in the panel. To check for the cross-sectional dependence is vital, to choose the right tools for examining the integration and cointegration properties of the variables and for the estimation of the relationship between the exchange rate and the import prices afterwards. A strong cross-sectional dependence if not dealt with could lead to an oversized panel unit root and cointegration tests and biased estimates of the slope coefficients in Equation (9) (e.g., see, Chudik, Pesaran & Tosetti, 2011; Pesaran, 2015; Demetrescu and Homm, 2016).
To check the cross-sectional dependence in the panel with country cross-sections for each variable in Eq. (9), we use the CD test of Pesaran (2015). The null hypothesis of the test assumes weak cross-sectional dependence. Rejection of the null implies an indication of the existence of strong cross-sectional dependence (Arsova, 2020).
The test statistic is calculated as the standardized average of the pairwise correlation coefficients between the series in the panel and are normally distributed under the null hypothesis. Table 2 presents the result of the CD test of Pesaran (2015).

Table 2: CD test of Pesaran (2015)

Variables	CD Test statistics	p-value	mean ρ	mean abs(ρ)
lnmp	29.30	0.0000	0.91	0.91
lner	27.41	0.0000	0.85	0.85
lny	31.07	0.0000	0.97	0.97
lnw	22.62	0.0000	0.70	0.70

mean ρ *shows the average pairwise correlation coefficient whereas* ***mean abs(ρ)*** *implies that the average absolute pairwise correlation coefficient over cross-sections.*

The null hypothesis of cross-section independence (weak cross-sectional dependence), CD ~ N(0,1) is rejected for all variables. The P-values close to zero shows that variables are correlated across panel groups. This is anticipated, considering the close economic and financial associations between the SSA countries. Therefore, the analysis went ahead noting the existence of strong cross-sectional dependence.

4.1.2 Panel unit root tests

All the asymptotic theory for STR models and the PSTR model extended by Gonzalez et al. (2005) are for stationary regressors. Results of panel unit root tests are reported in Table 2. From this table, it can be noted that panel unit root tests, Im, Pesaran and Shin (2003) (IPS), Maddala and

Wu (1999) (MW) panel unit root tests which assume cross-section independence and the Pesaran (2007) (CIPS) panel unit root test which assumes cross-section dependence all fail to reject the null hypothesis that series are I(1) at 5% level of significance for all panel time-series at levels.

Table 3: Panel unit root tests

Variables	Test	IPS	MW	CIPS	Order of Integration
lnmp	level	0.347 (0.635)	8.566 (0.930)	-1.600 (0.055)	I(1)
	First difference	-6.835 (0.000)	63.768 (0.000)	-5.277 (0.000)	
lner	level	0.778 (0.781)	6.992 (0.973)	-1.254 (0.105)	I(1)
	First difference	-4.492 (0.000)	33.091 (0.007)	-3.961 0.000	
lny	level	2.206 (0.986)	7.975 (0.950)	0.629 (0.735)	I(1)
	First difference	-3.385 (0.000)	37.357 (0.002)	-2.686 (0.004)	
lnw	level	-0.145 (0.442)	10.722 (0.826)	-0.630 (0.264)	I(1)
	First difference	-4.440 (0.000)	51.382 (0.000)	-1.806 (0.035)	

Notes: *Values in parentheses are p-values. *Denotes rejection of the unit root hypothesis at the 5% threshold. Null for MW and CIPS tests: series is I(1).MW test assumes cross-section independence. CIPS test assumes cross-section dependence is in form of a single unobserved common factor.*

4.1.3 The linearity test

The aim here is to determine whether there is a non-linear relationship between exchange rate and import price. Then, we carry out a test of linearity against the PSTR model. The null hypothesis is $H_0: \beta^1 = 0$ against the alternative $H_0: \beta^1 \neq 0$. As pointed out by Hansen, (1996). this test is not standard given that under the null hypothesis, the PSTR model has nuisance unidentified parameters. Following Luukkonen et al. (1988), we substitute the transition function with its first-order Taylor around $\gamma = 0$. Then, the null hypothesis will be $H_0: \gamma = 1$. When rewritten, the regression will be express as follows:

$$\boldsymbol{lnmp_{it} = \mu_i + \beta_1^{*0} lner_{it} + \beta_2^{*0} lny_{it} + \beta_3^{*0} lnw_{it} + [\beta_1^{*1} lner_{it} + \beta_2^{*1} lny_{it} + \beta_3^{*1} lnw_{it}]\, g(lner, \gamma, c) + \varepsilon_{it}} \quad \textbf{(4)}$$

where the vectors of parameter $\boldsymbol{\beta^{*1}} \ldots \boldsymbol{\beta^{*m}}$ are multiples of $\boldsymbol{\gamma}$ and $\boldsymbol{\varepsilon_{it}}$ is $\boldsymbol{\varepsilon_{it}}$ plus the residue of Taylor's development. Therefore, the null hypothesis of the linearity test becomes $H_0: \boldsymbol{\beta^{*1} = \cdots \beta^{*m} = 0}$.

A standard test is used to test the linearity. The study applied a Wald test which is expressed as follows:

$$\boldsymbol{LM_W = NT(SSR_0 - SSR_1)/SSR_0}$$

where $\boldsymbol{SSR_0}$ and $\boldsymbol{SSR_1}$ are the panel sum of square residuals under $\boldsymbol{H_0}$ (linear panel model with individual effects) and the panel sum of square residual under $\boldsymbol{H_0}$ (PSTR model with m regimes) respectively. Gonzalez *et al.* (2005) recommend the Fisher test if using a small size sample. The

Fisher test is specified as:

$$LM_F = \frac{\frac{NT(SSR_0 - SSR_1)}{mk}}{\frac{SSR_0}{TN - N - mk}}$$

$\boldsymbol{k}$ is the number of independent variables. LM_F follows a Fisher distribution where mk and $TN - N - mk$ degrees of freedom ($F\,(mk, TN - N - mk)$). The linearity tests are all distributed $\chi^2(k)$ under the null hypothesis.

Table 4 presents the results of linearity tests where it can be observed that the hypothesis of linearity of the model is rejected at 1% significance levels. The rejection of linearity is stronger for the logistic specification (m = 1) as such preferred to exponent one (m = 2). The results indicate that there exists a non-linear relationship between the exchange rate and the import price in the SSA countries.

Table 4: Linearity tests

Variable	m = 1		m = 2	
	Statistics	**P-value**	**Statistics**	**P-value**
Wald Tests (LM_W)	13.709	0.001***	17.015	0.002***
Fisher Tests (LM_F)	7.004	0.001***	4.382	0.002***
LRT Tests (LRT)	14.246	0.001***	17.854	0.001***

*Note: ***, **, * indicate statistical significance at 1% and 5% level of significance, respectively.*

4.1.4 The number of regimes test: Tests of no remaining non-linearity

Having rejected the null of linearity above, the aim here is then to test the null hypothesis (H0: r =1) whether there is one transition function against the alternative hypothesis that there are at least two transition functions (H1: r = 2). Results from Table 5 indicate that we fail to reject the null hypothesis that there is one transition function. This means that the relationship between import price and the exchange rate has only one threshold function.

Table 5: The number of regimes test

Variables	Statistics	P-value
Wald Tests (LM_W)	1.323	0.516
Fisher Tests (LM_F)	0.616	0.541
LRT Tests (LRT)	1.328	0.515

Note: H0: PSTR with r = 1 against H1: PSTR with at least r = 2

4.2 PSTR Estimation Result

The theoretical literature suggested the potential nonlinear ERPT (see Pollard and Coughlin 2004, Frankel et al. 2012 and Bussi`ere 2013). Accordingly, some empirical studies confirm that the nonlinearity in the ERPT (Delatte and Lòpez-Villavicencio 2012, Brun-Aguerre et al. 2016; Kassi et al. 2018 and Musti, 2020). Previous studies on ERPT for SSA are very few and at the country level and disregard the potential nonlinear and asymmetric ERPT to import price. The study examined a panel of eight SSA countries using the PSTR model and taking into cognizance the cross-sectional dependence between countries with the aims of filling the gap in the ERPT literature in the SSA countries. Table 5 present the PSTR estimation results.

Table 6: PSTR estimation result.

Linear part (first extreme regime)			
variables	**coefficient**	**Standard error**	**t-statistics**
lner	-1.2370	1.0780	-1.1475
lny	2.2350	5.7260	0.3903
lnw	0.5579	2.3680	0.2356
Non-linear part			
variables	**coefficient**	**Standard error**	**t-statistics**
lner	2.0890	2.2230	0.9397
lny	-4.0950	11.3100	-0.3621
lnw	-0.8046	4.6160	-0.1743
Second extreme regime			
variables	**coefficient**	**Standard error**	**t-statistics**
lner	0.8518	1.1610	0.7337
lny	-1.8610	5.5870	-0.3331
lnw	-0.2468	2.2490	-0.1097
Non-linear parameter estimates			
variables	**coefficient**	**Standard error**	**t-statistics**
γ	0.63	0.5451	1.1557
C	0.00002	0.1760	0.00001
The estimated standard deviation of the residuals 0.05175			

Notes: * indicate the statistical significance and the rejection of the null hypothesis at 5%.

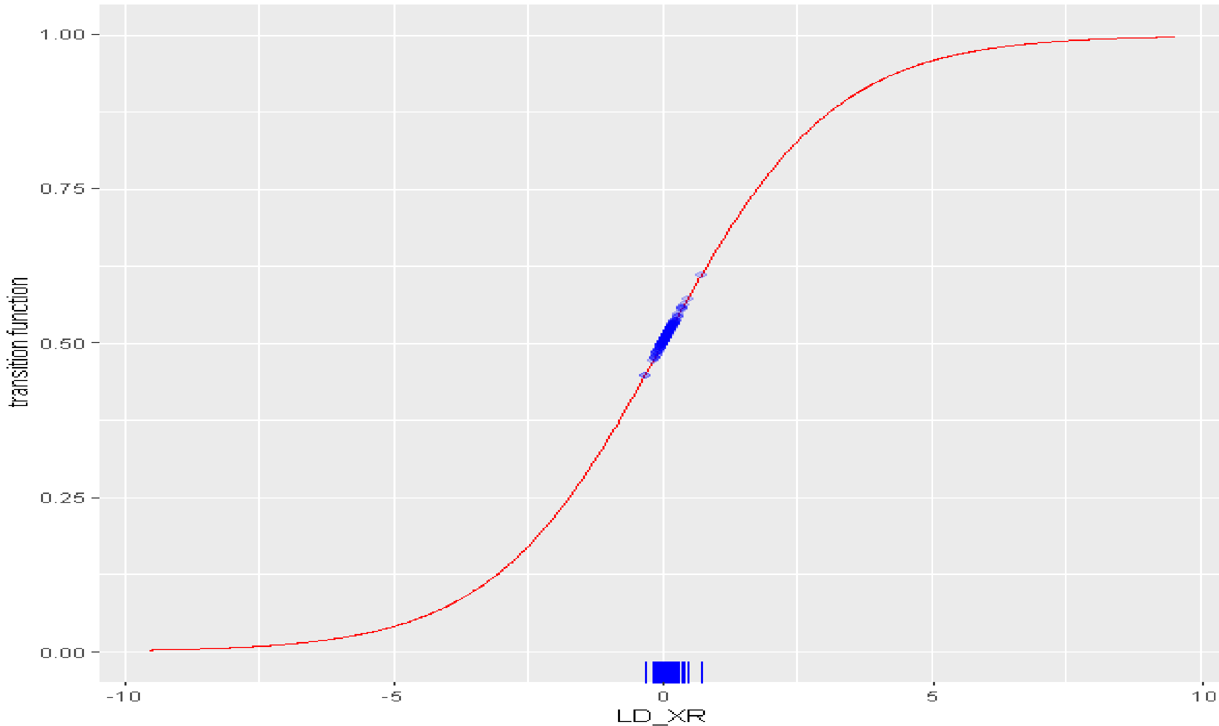
The results in Table 6 show no significant influence of the transition variable (exchange rate) on the import price. Note that, the coefficients cannot be directly interpreted as the ERPT coefficient. Even though the linearity test rejected the null hypothesis of linearity against nonlinear PSTR, the coefficients are not significant for both the linear and the nonlinear part of the PSTR as evidenced in Table 5. The result of the Linear panel regression with fixed effect estimated and results presented in Table 6 shows that the coefficient of the lner (log of the exchange rate) and lnw (log of exporting countries cost) are statistically significant. However, the estimated standard deviation of the residuals estimated for both the PSTR, and the Linear panel regression shows that the PSTR is more efficient.

Table 7: Linear panel regression with fixed effects estimation

variables	**coefficient**	**Standard error**	**t-statistics**
lner	-0.1477	0.0494	-2.9881*
lny	0.1092	0.0975	1.1206
lnw	0.1818	0.0851	2.1353*
Estimated standard deviation of the residuals 0.05297			

Notes: * indicate the statistical significance and the rejection of null hypothesis at 5%.

The figures also did not show a clear non-linearity which exists between exchange rate and import price as depicted in Fig 1.



The weak nonlinearity in the relationship between exchange rate and import price in the SSA countries could be attributed to the high rate of inflation in the countries of the region. The analysis of the data shows that within the period under review there was hardly appreciation of the local currencies exchange rate. As such the data distribution would not allow the nonlinearity that could occur if there is the appreciation of the local currencies. This finding suggests, contrary to previous studies in the SSA and some other regions that show nonlinearity in ERPT.

5. Conclusions

This paper examines the potential nonlinearity in the relationship between the exchange rate changes and the import price in 8 sub-Saharan African (SSA) countries from 1997 to 2019 using the Panel Smooth Transition Regression (PSTR) approach along with cross-sectional dependence analysis. First, the results suggest rejection of linearity against PSTR ERPT in the SSA countries. However, the estimation result of the PSTR fails to show a significant coefficient for the parameters both in the linear and nonlinear parts of the estimation even though the estimated standard deviation shows that the PSTR model is more efficient. The estimation of the Panel regression with fixed effect shows that the exchange rate and the cost of exporting have a significant impact on the import price. This result echoes the downward price rigidities in the SSA countries. The nonlinearity in the ERPT in the SSA countries was not significant against the findings of Kassi et al. 2018 who use the NARLD approach. However, ignoring the cross-sectional dependence in their analysis of ERPT could result in biased conclusions.

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Appendix

Appendix 1: Descriptive Statistics of the Variables

	lnmp	lner	lny	lnW
Mean	-0.627887	3.975890	10.62777	4.812465
Median	-0.595627	3.813976	10.30364	4.915394
Maximum	-0.407037	8.223378	13.82173	6.221397
Minimum	-0.912580	-1.585740	7.884238	2.912300
Std. Dev.	0.124036	2.387648	1.868730	0.602087
Skewness	-0.471874	-0.063675	0.271413	-0.758434
Kurtosis	2.235925	2.113749	1.803834	3.917360
Jarque-Bera	11.30428	6.146049	13.22864	24.09204
Probability	0.003510	0.046281	0.001341	0.000006
Sum	-115.5312	731.5637	1955.510	885.4936
Sum Sq. Dev.	2.815423	1043.258	639.0637	66.33904
Observations	184	184	184	184