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NONLINEAR AND ASYMMETRIC EXCHANGE RATE PASS-THROUGH TO CONSUMER PRICES IN NIGERIA: EVIDENCE FROM A SMOOTH TRANSITION AUTOREGRESSIVE MODEL

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Abstract

This paper examines the nonlinearities and asymmetries in the exchange rate pass-through (ERPT) to consumer prices in Nigeria using quarterly time series data from 1986 to 2013 and the nonlinear smooth transition autoregressive (STAR) method. The standard literature assumes linearity and symmetry in the ERPT to consumer prices in a developing country, despite the importance and presence of potential asymmetries and nonlinearities which are generated by the presence of various factors such as menu costs, capacity constraints, market share objectives and production switching. This study develops a partial equilibrium microeconomic mark-up model to investigate asymmetric and nonlinear behaviour in the ERPT. The study confirms the presence of nonlinear ERPTs due to different inflation levels. The results also show asymmetric ERPTs in the appreciation and depreciation of exchange rates. The magnitude of the ERPT also depends on the size of the exchange rate change. The ERPT is higher during depreciation than during the appreciation episodes of the Naira; nonlinearity is more prevalent during the high inflationary period of the 1990s than in other periods. The policy implication of the results is that the government, despite temptations to do so, should avoid the devaluation of the Naira during high inflation periods in order to reduce the impact on consumer prices and the associated costs.

Keywords: Exchange rate pass-through; Asymmetry; Nonlinearity; Nigeria.
JEL codes: F30; F40;

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1. Introduction

This paper examines potential nonlinearities and asymmetries in the exchange rate pass-through (ERPT) to consumer prices in Nigeria using quarterly time series data from 1986 to 2013 and the nonlinear smooth transition autoregresive (STAR) method. The ERPT represents the transmissions of changes in the exchange rate to prices of consumer goods and services. The overall ERPT takes place in two stages: The first stage is from exchange rate to import prices and the second stage is from import prices to consumer prices.

The existing literature based on the linear and symmetric ERPT modelling approach provides conflicting results (see Aliyu *et al.* 2009 and Essien 2005), which cannot capture the true data generation process in the presence of nonlinear and asymmetric types of the ERPT. There are several factors such as importing firms' capacity constraints, market share objectives, production switching and menu costs which could cause asymmetric and nonlinear ERPT.

Empirical studies generally either examine the first stage or the second stage ERPT, but not both stages together in assessing the overall ERPTs. We fill the gap in this paper by assessing the overall ERPT in a developing country - Nigeria. High rates of inflation have been a serious macroeconomic concern in Nigeria, especially since the adoption of the floating exchange rate regime in 1986. As far as we are aware, no empirical study for Nigeria exists on this topic. This paper will improve our understanding of these issues by examining the nonlinear and asymmetric impact of the ERPT on inflation in a developing country such as Nigeria using the most up to date econometrics techniques.

There is the possibility of directional asymmetries - that depreciation could cause a different price reaction compared to an appreciation – a well as nonlinearities, where smaller changes might lead to a disproportionate response compared to larger changes. Asymmetries could occur from strategic considerations and downward price rigidities. Nonlinearities could result from factors such as menu costs, the market share strategies of importing firms and the inflationary and macroeconomic environment. It is assumed that different inflation and macroeconomic environments cause nonlinearities in the ERPT. Importing firms in Nigeria face competition from locally produced goods, which tend not to pass-through but absorb minor exchange rate changes in their profit margins. On the other hand, a pass-through takes place when the changes in exchanges rates exceed a given threshold level if the changes are considered to be significant. Importing firms may also fail to change their prices immediately due to the cost of changing their menus unless or until the change in the exchange rate exceeds a certain threshold level. Prices are also not adjusted in response to a temporary shock in the exchange rate as opposed to the permanent one.

The remaining sections of the paper are organised as follows. In section two, a theoretical model of asymmetric ERPT is developed. Section three explains the methodology applied to this paper. Section four explains the empirical specifications of the theoretical model. Section five analyses and discusses the empirical results. Section five draws conclusions from this paper.

2. A Theoretical Model of the Asymmetric and Nonlinear Exchange Rate Pass-Through to Consumer Prices (ERPT)

A theoretical model to explain the key causes of the asymmetric and nonlinear ERPT to consumer prices is developed in this section. Consider a foreign firm which produces and exports product i to an importing country. A profit maximising firm in a competitive market follows the following pricing policy:

$$P_i = E^{\beta} \, W_i^{*\varphi} \tag{2.1}$$

Where W_i^* is the marginal cost of the firm in the exporting country's currency E is the exchange rate, expressed as the importing country's currency value of a unit of the exporting country's currency. In the absence of a competitive market in a developing country such as Nigeria, a profit maximising firm will follow the following mark-up pricing policy:

$$P_i = AE^{\beta} \, {\pi_i}^{\delta} W_i^{*\varphi} \tag{2.2}$$

Where π_i is a mark-up on the marginal cost W_i^*.The constant is given by A. Equation (2.2) shows that the local currency price of the product can vary due to change in the exchange rate, a change in the firm's marginal cost, and/or a change in the importers' markup. Note also that the marginal cost and markup of the firm can change independently of the exchange rate. For instance, the marginal cost can shift due to change in the cost of a locally provided input in the exporting country. Also, the level of demand in the importing country can alter the exporter's markup. It is, therefore, imperative to take into account movements in these other determinants of the price while estimating pass-through to appropriately isolate the effects of exchange rate changes on consumer prices.

Following Bailliu and Fujii (2004), Campa and Goldberg (2005) and Nogueira Jr. and Leon-Ledesma (2011), our model assumes that the demand pressures in the importing country influence the markup: $\pi_i = \pi(\mathrm{Y})$ where, Y is the output level in the importing country which is used as a proxy for demand pressures.

A log-linear approximation to equation (2.2) provides a basis for the standard ERPT regression often used throughout the ERPT literature (see for example Goldberg and Knetter (1997) Bailliu and Fujii (2004), Campa and Goldberg (2005) and Nogueira Jr. and Leon-Ledesma (2011)).

$$p_t = \alpha + \beta e_t + \delta y_t + \varphi w_t^* + \varepsilon_t \tag{2.3}$$

Where lower case letters indicate the logarithms of the variables. In equation (2.3), the ERPT coefficient is given by β and is expected to be bounded between 0 and 1. When β = 1, the price responds to changes in the exchange rate and the price is set in the exporting country's currency, which is a strategy known as producer-currency pricing (PCP) and so there will be complete pass-through. When β = 0, the pass-through is zero, so that the importing firm decides not to change the prices in the importing country's currency and absorbs the variation in their markup. This is the strategy called local-currency pricing (LCP).

However, the pricing strategies of the importing firm may not depend exclusively on demand conditions in the importing country. Because of the instability in a developing country such as Nigeria, it can be argued that the foreign firm's pricing strategies could be influenced by some macroeconomic factors other than demand conditions. For instance, Taylor (2000) argued that the inflation environment could influence the level of ERPT. Taylor (2000) suggested that ERPT would be higher in a high inflation environment than in an environment with low and stable inflation. This is, in fact, the case in Nigeria considering the period of high exchange rate depreciation and high inflation witnessed in the 1990s. Therefore, the importing firm is more likely to implement an LCP strategy when there is a stable inflation environment in the importing country. The importing firm can then absorb the exchange rate changes within its markup, which will lead to low level of pass-through. Whereas, when there is high inflation in the importing country, the importing firm will adopt a PCP strategy which leads to higher or full pass-through.

A business cycle is another cause of nonlinearity in ERPT. The importing firms are more willing to pass-through cost increases resulting from exchange rate changes to the prices during an economic boom than in a recession. Therefore, the business cycle could lead to a nonlinear transmission of changes in the exchange rate to consumer prices. It is expected that the pass-through would be higher during a boom than during a recession. (See, for example, Delatte and Lopez-Villavicencio (2012)). The boom and bust cycle is more prevalent in developing countries such as Nigeria that have an undiversified economy which have relied on the export of a sole product. For instance, Nigeria has mainly relied on petroleum exports for its foreign exchange earnings and government revenues.

Likewise, the presence of menu costs is also another factor which compels the foreign firm to adjust prices nonlinearly according to the size of the change in the exchange rate. Due to the menu costs, the importing firm may not adjust the price in the importing country when the exchange rate change is small. The importing firm only changes the price when the change in exchange rate exceeds a certain threshold. This leads to nonlinearity, as the ERPT varies with the size of the exchange rate change. Despite the seeming ease in changing the menu with the advances in information technology, in developing countries such as Nigeria, transactions via e-commerce are minimal. Therefore, there are still costs involved in changing the menu.

More so, where the importing firm's aim is to maintain a market share, importers will adjust their markups to absorb the changes when the importing country's currency depreciates. However, the importing firms pass through the changes to the price when the importing country's currency appreciates. This leads to an asymmetric ERPT, where the appreciation of the importing country's currency will lead to a higher ERPT than the depreciation of the currency.

Based on the arguments above, it is assumed that the foreign firm's pricing strategy depends nonlinearly on the macroeconomic environment and the demand shocks in the importing country. This study followed Nogueira Jr. and Leon-Ledesma (2011) and Cheikh (2012), to consider $\omega(m)$ as a function of the macroeconomic determinants such as inflation level and output growth. This macroeconomic dependence is perceived as a foreign firms' strategic decision on the amount of the exchange rate changes to transmit to the prices considering different macroeconomic scenarios in the importing country.

Consequently, incorporating the macroeconomic factors mentioned above, the foreign firm's markups can be rewritten as follow:

$$\pi_i = \pi\left(Y, E^{\omega(m)}\right), \qquad \omega(m) \geq 0, \tag{2.4}$$

Where Y represents the demand pressures in the importing country which are proxied by the output level in the economy. As stated earlier, the mark-up is affected nonlinearly by the macroeconomic stability in the economy which is represented by a component m. A higher value for m is a tantamount to a higher rate inflation level; hence m is a measure of economic stability. This study has assumed that the mark-up and marginal cost can change independently of the exchange rate. For instance, a change in the cost of locally sourced input in the exporting country may shift the marginal cost; a change in demand in the importing country could affect the firm's mark-up.

Changes in the exchange rate are transmitted to consumer prices via direct and indirect channels. The changes in the exchange rate are transmitted directly to consumer prices through their impact on the import prices of finished goods and raw materials. For instance, when Nigeria's currency (Naira) depreciates, import prices (in Naira) of the imported finished goods and raw materials will become more expensive, which ultimately raises the consumer prices. The proportion of the changes in the exchange rate and import prices passed on to consumer prices depends on the pricing decisions of the importing firm. The indirect channel of the transmission of the exchange rate changes to consumer prices is through production costs and real channels. Depreciation in the Naira value will result in higher cost of production as the imported inputs will become more expensive, and that will eventually have the effect of increasing domestic consumer prices.

Substituting equation (2.4) for π_i in (2.2), a log-linear approximation of equation (2.2) can be expressed as follows:

$$p_t = \alpha + \beta e_t + k y_t + \omega(m) e_t + \varphi w_t^* \qquad (2.5)$$
$$= \alpha + [\beta + \omega(m)]\, e_t + k y_t + \varphi w_t^* + \varepsilon_t$$

where the lower-case letters in equation (2.5) are logarithms of the upper cases in equation (2.2). Equation (2.5) shows the two ERPT channels: direct and indirect. The direct channel is denoted by β, which is to be bounded between 0 and 1. The indirect channel denoted by the function $\omega(m)$, which is influenced by the macroeconomic environment, with w_t^* representing the costs and y_t standing for the output level.

Following Korhonen and Juntilla (2012) and Nogueira Jr. and Leon-Ledesma (2011), we assume that there is some threshold m^* that defines the extreme regimes of higher inflation, which is represented by higher values of m; low inflation is represented by the lower value of m.

$$\omega(m) = \begin{cases} 0; m \leq m^* \\ \psi > 0; m > m^* \end{cases} \tag{2.6}$$

For the two regimes, there will be different levels of pass-through. When the importing country is in a period of higher inflation, the ERPT will be equal to $\alpha + \psi$; when the importing country is in a period of lower inflation, the ERPT will be equal to α. Hence the ERPT is higher during higher inflation as $(\alpha + \psi) > \alpha$.

Consequently, the ERPT is different depending on whether the macroeconomic determinant is below or above some threshold. For instance, a higher inflation environment raises ERPT, while there will be low ERPT with a stable inflation environment. Therefore, equation (2.5) appropriately describes the changing behaviour of the ERPT nonlinearly in developing country such as Nigeria. In the next section, we specify the empirical model based on the theoretical model discussed here.

3. Methodology

The paper uses a smooth transition autoregressive (STAR) Model. STAR models are a set of nonlinear time series models which are characterized by switching regimes through continuous transition functions. The transition dynamics depends on continuous transition functions that allow for smooth changes during the transition. The standard smooth transition autoregressive regression model has the following form:

$$y_t = \phi' z_t + \theta' z_t G(s_t, \gamma, c) + u_t \, , \tag{3.1}$$

Where:

- ✓ $\phi = (\phi_0, \phi_1, \dots, \phi_m)'$ and $\theta = (\theta_0, \theta_1, \dots, \theta_m)'$ are parameter vectors of the linear and nonlinear part respectively.
- ✓ $z_t = (V_t', X_t')'$ is ((m+1)×1) vector of explanatory variables $V_t' = (1, y_{t-1}, \dots, y_{t-d})'$ and $\boldsymbol{X}_t = (x_{1t}, \dots, x_{kt})'$

- ✓ G represents a continuous transition function usually bounded between 0 and 1. Due to this reason, the model explains not only the two extreme states but also a continuum of states that lie between the two extremes.
- ✓ s_t is a transition variable which is an element of $\boldsymbol{z}_t$, and then is assumed to be a lagged endogenous variable $s_t = y_{t-d}$ or an exogenous variable $s_t = x_{kt}$, s_t is usually one of the explanatory variables or the time trend.
- ✓ γ is a slope parameter which measures the speed of the transition from one regime to another.
- ✓ $c = (c_1, \ldots, c_k)'$ is a vector of location parameters.
- ✓ $u_t \sim \text{iid}(0, \sigma^2)$ denotes a sequence of independent identically distributed errors.

There are two possible interpretations of the STAR model. The STAR model can be considered as a regime-switching model that allows for two regimes, connected with the extreme values of the transition function, $G(s_t, \gamma, c) = 1$ and $G(s_t, \gamma, c) = 0$ where the transition between the two regimes is smooth. On the other hand, the STAR model can be considered as a model which allows for a ‘‘continuum’’ of regimes, each associated with a different value of $G(s_t, \gamma, c)$ between 0 and 1. This study we will use the two-regime interpretation.

The observable variable s_t determines the regime that takes place at time t and the associated value of $G(s_t, \gamma, c)$. Different regime-switching behaviours are observed which are based on the choices of the transition function $G(s_t, \gamma, c)$. The first-order logistic function is often the choice for $G(s_t, \gamma, c)$ and the resultant model is referred to as the logistic STAR (LSTAR) model expressed as follows:

$$G(s_t, \gamma, c) = [(1 + \exp\{-\gamma(s_t - c)\})^{-1}], \qquad \gamma > 0, \tag{3.2}$$

In equation (3.2) the parameter c denotes the threshold between the two regimes, so that the logistic function changes monotonically from 0 to 1 as s_t increases and $G(s_t, \gamma, c) = 0.5$. The parameter γ determines the smoothness of the change in the value of the logistic function and, hence, the smoothness of the transition from one regime to the other. As γ grows very large, the logistic function $G(s_t, \gamma, c)$ approaches the indicator function $|[s_t > c]$, defined as $|[A] = 1$, if A is true and $|[A] = 0$ otherwise, and, consequently, the change of $G(s_t, \gamma, c)$

from 0 to 1 becomes instantaneous at $(s_t = c)$. Therefore, the LSTAR model in Equation (3.2) nests a two-regime threshold autoregressive (TAR) model as a special case. In the case $s_t = y_{t-d}$, this model is called a self-exciting TAR (SETAR) model (for example see Tong 1990). As $\gamma \rightarrow \infty$, the logistic function approaches a constant (equal to 0.5) and when $\gamma = 0$, the LSTAR model will, be reduced to a linear AR model with parameters $\phi_j = \frac{\phi_{1,j}+\phi_{2,j}}{2}$, $j = 0,1 \dots, p$.

With LSTAR model, the two regimes are associated with small and large values of the transition variable s_t (relative to c). This type of regime-switching can be convenient for modelling, for example, business cycle asymmetry where the regimes of the LSTAR are related to expansions and recessions (for example see Terasvirta and Anderson (1992) and Skalin and Terasvirta (2001)).

Some applications specify the transition function in a way that the regimes are related to small and large absolute values of s_t (again relative to c). This can be achieved by using, for example, the exponential function expressed follows.

$$G(s_t, \gamma, c) = \quad (1 - exp\{-\gamma(s_t - c)^2\}), \qquad \gamma > 0, \tag{3.3}$$

The exponential function has the property that $G(s_t, \gamma, c) \rightarrow 1$ both as $s_t \rightarrow -\infty$ and $s_t \rightarrow \infty$ whereas $G(s_t, \gamma, c) = 1$ for $s_t = c$. The exponential STAR (ESTAR) model has been applied with $s_t = y_{t-d}$ to real (effective) exchange rates by Michael et al. (1997), Sarantis (1999) and Taylor et al. (2001), motivated by the argument that the behaviour of the real exchange rate depends nonlinearly on the size of the deviation from purchasing power parity.

For either $\gamma \rightarrow 0$ or $\gamma \rightarrow \infty$, the exponential function (3.3) approaches a constant (equal to 0 and 1, respectively). Therefore, in both cases the model collapses to a linear model and, particularly, the ESTAR model does not nest a SETAR model as a special case. Alternatively, one can use the second-order logistic function.

$$G(s_t, \gamma, c) = [(1 + \exp\{-\gamma(s_t - c_1)(s_t - c_2)\})^{-1}], \quad c_1 \leq c_2, \quad \gamma > 0, \tag{3.4}$$

Where, $c = (c_1, \ c_2)'$as proposed by Jansen and Terasvirta (1996). Here, as $\gamma \rightarrow 0$, the model becomes linear, while as $\gamma \rightarrow \infty$, and $c_1 \neq c_2$, the function $G(s_t, \gamma, c)$ becomes equal to 1 for $s_t < c_1$ and $s_t < c_2$ and equal to 0 in between. Therefore, the STAR model with this particular transition function nests a restricted three-regime (SE)TAR model, where the restriction is that the linear models in the outer regimes are identical. The minimum value of the second-order logistic function, attained for $s_t = (c_1, +c_2)/2$, remains between 0 and 1/2, unless $\gamma \rightarrow \infty$. While interpreting the estimate from models with this particular transition function, the fact that the minimum value does not equal zero has to be considered in the latter case.

In the end, the transition functions (3.2) and (3.4) are special cases of the general nth-order logistic function which can be used to obtain multiple switches between the two regimes. The general nth-order logistic function is expressed as follows:

$$G(s_t, \gamma, c) = \left[\left(1 + \exp\left\{-\gamma \prod_{i=1}^{n}(s_t - c_1)\right\}\right)^{-1}\right], \quad c_1 \leq c_2 \leq \cdots \leq c_n\,, \;\; \gamma > 0, \tag{3.5}$$

The STAR Modelling Approach

The modelling cycle for STAR models put forward by Terasvirta (1994) follows this approach and consists of the following steps.

1. Specify a linear AR model of order p for the time series under investigation using an appropriate model selection criterion.

2. Test the linearity against the alternative of STAR nonlinearity. If the test rejects linearity, select the appropriate transition variable s_t and the form of the transition function $G(s_t, \gamma, c)$.

3. Estimate the parameters in the selected STAR model.

4. Evaluate the model, using diagnostic tests and impulse response analysis.

5. Modify the model if necessary.

6. Use the model for descriptive or forecasting purposes.

A discussion of the three most critical stages of specification, estimation and evaluation follow below:

Specification stage

The specification comprises two phases. First, the linear baseline model will be specified and tested for linearity and then the appropriate transition variable s_t and type of STAR model

(LSTR or ESTR) is selected. The economic theories will form the basis of variables to include in the linear model.

Following Terasvirta (1998), LM type tests are used to verify the null hypothesis of linearity against STAR nonlinearity. The STAR model just as with some other nonlinear model has a property that the model is only identified under alternative but not the null hypothesis of linearity (Hansen 1996). However, the problem in testing linearity could be resolved by approximating the transition function in (3.1) by a Taylor expansion around the null hypothesis $\gamma = 0$ (Lutkepohl and Kratzig, 2004). The F-versions of the LM test statistics are used considering that they have better size properties compared to the chi square variants as suggested by Van Dijk, Terasvirta, and Franses (2002).

The linearity of the predetermined transition variable is tested against a STAR model. Where economic theory is not explicit about this variable the test is repeated for each of the predetermined potential transition variables, which is usually a subset of the element in $\boldsymbol{z}_t$. The test is used to test the linearity against different directions in the parameter space. If the test result was unable to reject the null hypothesis, then the linear model will be accepted and the STAR model will not be used. The test results are also used for model selection. If the null hypothesis is rejected for at least one model of the models the model with the strongest rejection measured with p-value will be chosen as the STAR model to be estimated (Terasvirta, 1998).

The linearity test is used to check if nonlinearity of the STAR type exists in the model. It also aids to determine the transition variable and whether ESTR or LSTR should be employed. The following auxiliary regression is applied if $\boldsymbol{s}_t$ is an element of $\boldsymbol{z}_t$:

$$y_t = \beta_0' z_t + \sum_{j=1}^{k} \beta_j' \tilde{z}_t s_t^j + u_t^* \tag{3.6}$$

$\boldsymbol{z}_t = (1, \tilde{\boldsymbol{z}}_t)'$.

In case $\boldsymbol{s}_t$ is not part of $\boldsymbol{z}_t$

$$y_t = \beta_0' z_t + \sum_{j=1}^{k} \beta_j' z_t s_t^j + u_t^* \tag{3.7}$$

The null hypothesis of linearity is $H_0: \ \beta_0 = \beta_1 = \beta_2 = \beta_3 = 0$. This linear restriction is checked by applying the *F* test.

Once linearity has been rejected, the model type is to be chosen. That is whether an LSTR or an ESTR model should be specified. The choice will be based on the following test sequence:

1. Test $H_{04}: \ \beta_3 = 0$

2. Test $H_{03}: \beta_2 = 0 | \beta_3 = 0$

3. Test $H_{02}: \beta_1 = 0 | \beta_2 = \beta_3 = 0$

The test is based on the auxiliary regression (3.6 and 3.7) as the linearity test. Where the test sequence does not provide a clear-cut choice between the alternatives, the decision will be left to the evaluation stage.

ii. Estimation stage

After the transition variable $\boldsymbol{s}_t$ and the transition function $G(s_t, \gamma, c)$ have been selected, the next stage in the modeling cycle is an estimation of the parameters in the STAR model. The parameters of the STAR model will be estimated by a nonlinear optimization routine. It is important to use good starting values for the algorithm to work.

Starting Values

The grid-search creates a linear grid in c and a log-linear grid in γ. For each value of γ and *c*, the residual sum of squares is computed. The values that correspond to the minimum of that sum are taken as starting values. In order to make γ scale-free, it is divided by $\hat{\sigma}_s^K$ the kth power of the sample standard deviation of the transition variable.

$$G(s_{t-i}, \gamma, c) = \left(1 + exp\left\{-1(\gamma/\hat{\sigma}_s^K) \prod_{k=1}^{K} (s_t - c_k)\right\}\right)^{-1}, \gamma > 0. \tag{3.8}$$

The slope parameter in the equation (3.8) above is scale-free, which in turn facilitates the construction of an effective grid. To maximize the conditional maximum likelihood function, once good starting values were recognised, the unknown parameters can be estimated using a form of the Newton-Raphson algorithm.

The Estimate of γ

It is hard to get an exact estimate of the smoothness of the transition between the two regimes, represented by γ, where this parameter is large. This is owing to the fact that for such large values of γ, the STAR model is like a threshold model, as the transition function draws closer to a step function. To get an accurate estimate of γ, there is a need for many observations in the immediate area of c, considering that even big changes in γ only have a little effect on the shape of the transition function. The estimate of γ could therefore be quite imprecise and often turn out to be insignificant when evaluated by its t-statistic. This should not be interpreted as an indication of weak nonlinearity, given that the t-statistic does not have its usual asymptotic t-distribution under the hypothesis that γ = 0, owing to some identification problems. In such circumstances, the causes of the large standard error estimate are simply numerical. Moreover, because large changes in γ have only a slight effect on the transition function, high precision in estimating γ is not crucial (Van Dijk, Terasvirta and Franses, 2002).

iii. Evaluation stage

The estimated STAR model will be evaluated before using it for any forecasting or policy making. Misspecification tests are used to check the quality of the estimated model just as it is being done in linear models. Researchers use various misspecification tests in the STAR literature. However, Terasvirta (1998) considered LM test of no error autocorrelation, an LM-type test of no addictive nonlinearity and LM test of parameter constancy. Asymptotic normality and consistency of the maximum likelihood are also necessary.

Test of no error autocorrelation:

The test of no error autocorrelation applicable to the STAR models is a unique type of a general test defined in Godfrey (1988), and its application to STAR was demonstrated in Terasvirta (1998). The estimated residual $\tilde{u}_t$ is regressed on lagged residuals $\tilde{u}_{t-1}$ ... $\tilde{u}_{t-q}$ and the partial derivatives of the log-likelihood function with respect to the parameters of the model. The test statistic is then

$$FLM = \left\{\frac{(SSR_0 - SSR_1)}{q}\right\} / \left\{\frac{SSR_1}{(T-n-q)}\right\} \tag{3.9}$$

Where n represents the parameters in the model, SSR_0 the sum of squared residuals of the STAR model and SSR_1 the sum of squared residuals from the auxiliary regression.

Test of No Additive Nonlinearity

Once the STAR has been fitted, then the model must be checked for remaining nonlinearity. The test is based on the assumption that the remaining nonlinearity is also of the STAR type. The alternative can be expressed as:

$$y_t = \phi' z_t + \theta' z_t G(\gamma_1, c_1, s_{1t}) + \psi' z_t H(\gamma_1, c_1, s_{1t}) + u_t \tag{3.10}$$

Where: H is another transition function and $u_t \sim iid(0, \sigma^2)$. The following auxiliary model will be used to test the alternative:

$$y_t = \beta' z_t + \theta' z_t G(\gamma_1, c_1, s_{1t}) + \sum_{j=1}^{3} \beta_j' \tilde{z}_t \, s_{2t}^j + u_t^* \tag{3.11}$$

The test will be carried out by regressing $\tilde{u}_t$ on $(\tilde{z}_t{}' s_{2t}, \ \tilde{z}_t{}' s_{2t}^2, \ \tilde{z}_t{}' s_{2t}^3)'$ and the partial derivatives of the log-likelihood function with respect to the parameters of the model. The null hypothesis of no remaining nonlinearity is that $\beta_1 = \beta_2 = \beta_3 = 0$. The choice of s_{2t} can be a subset of available variables in z_t or it can be s_{1t} . It is also possible to exclude certain variables from the second nonlinear part by restricting the corresponding parameter to zero. The resulting F statistics are given in the same way as for the test on linearity.

Test of Parameter Constancy

Test of parameter constancy tests the null hypothesis of constant parameters against smooth continues change in parameters. The alternative can be written as follows:

$$y_t = \phi(t)' z_t + \theta(t)' z_t G(\gamma_1, c_1, s_{1t}) + u_t \,, \quad u_t \sim iid(0, \sigma^2) \tag{3.12}$$

Where

$$\phi(t) = \phi + \lambda_\phi H_\phi\left(\gamma_\phi, c_\phi, t^*\right)$$

And

$$\theta(t) = \theta + \lambda_\theta H_\theta(\gamma_\theta, c_\theta, t^*)$$

With $t^* = T/t$ and $u_t \sim iid(0, \sigma^2)$ .The null hypothesis of no change in parameters is $\gamma_\phi = \gamma_\theta = 0$.

The parameters γ and c are assumed to be constant. The following nonlinear auxiliary regression is used:

$$y_t = \beta_0' z_t + \sum_{j=1}^{3} \beta_{j+3}' z_t\, (t^*)^j G(\gamma_1, c_1, s_{1t}) + u_t^* \quad (3.13)$$

The F-version of the LM test is preferred against the chi-square variants especially in a smaller sample as the latter could be oversized. The F-test results for the three alternative transition functions are given by

$$H(\gamma, c, t^*) = \left(1 + exp\left\{-\gamma \prod_{k=1}^{k} (t^* - c_k)\right\}\right)^{-1} - \frac{1}{2}, \gamma > 0 \quad (3.14)$$

Where K = 1, 2, 3, respectively and assuming $\gamma_\emptyset = \gamma_\theta$.

The standard tests carried out in the evaluation stage - the three tests of no error autocorrelation, no addictive nonlinearity and the parameter constancy described above. However, two further tests used include the LM-type test for no ARCH and the Jarque-Bera normality test.

4. Empirical Model Specification and result

4.1Empirical Model Specification

The empirical specification which is similar to those employed by Nogueira Jr. and Leon-Ledesma (2011), Cheikh (2012) and Shintani, Terada and Yabu (2013) which is based on the theoretical model described in sections 2 above. The STAR pass-through equation is expressed as a nonlinear backward-looking Phillips curve and has the following form:

$$\Delta cpi_t = \beta_0 + \sum_{i=1}^{n} \beta_{1,i} \Delta cpi_{t-i} + \sum_{i=0}^{n} \beta_{2,i}\, \Delta mpi_{t-i} + \sum_{i=0}^{n} \beta_{3,i} \Delta y_{t-i} + \sum_{i=0}^{n} \beta_{4,i} \Delta e_{t-i} + \left(\beta_0^* + \sum_{i=0}^{n} \beta_{4,i}^* \Delta e_{t-i} \right) G(s_t, \gamma, c) + \varepsilon_t \tag{4.1}$$

Where Δcpi is the inflation rate, Δmpi is the changes in import prices, Δy is output growth, Δe represents changes in exchange rates, $G(s_t, \gamma, c)$ is a nonlinear function, ε is an error term. It is also a common practise in the nonlinear modelling to include a time trend if it is statistically significant (see Clifton *et al.* 2001).

The ERPT test produces two sets of results. Either the transition variable is far below the threshold of the LSTR model or it is close to the threshold. The ERPT is then given by the linear parameters $\sum_{i=1}^{n} \beta_{4,i}$. On the other hand, if the transition variable is far away from the threshold for the ESTR model, or far beyond the threshold for the LSTR model, the coefficient is the sum of the linear and nonlinear parts of the model $\sum_{i=1}^{n} \beta_{4,i} + \sum_{i=1}^{n} \beta_{4,i}^*$. For the LSTR specification there is a third possible outcome: when the transition variable is equal to the threshold, the ERPT is given by $\sum_{i=1}^{n} \beta_{4,i} + \sum_{i=1}^{n} \beta_{4,i}^* /2$.

The study makes use of quarterly series for the period 1986Q4 to 2013Q4 for all variables. cpi is the consumer price index for 2010 as the base year, while er is the nominal exchange rate (a bilateral Naira per US Dollar exchange rate as a three-month average); mpi is import prices and y is a real gross domestic product (GDP).

Data were obtained from World Bank's World development indicators database and the Penn World Tables. The nominal exchange rate (e), consumer price index (cpi), Nigerian Real GDP(y), were generated from World Bank's world development indicator database. Import prices (mpi) were derived from the Penn World Table 8.1.

We checked all the series for non-stationarity using the ADF-test, unit root with break and Phillips-Perron (PP). The stationarity checks show that the variables are integrated of order I(1) (see Table 1 below). This study has chosen to follow standard practice in the literature and has estimated the model in differences (for example see, Nogueira, Jr. and León-Ledesma, 2011; Shintani, Terada and Yabu, 2013; Cheikh, 2012). The choice is based on the fact that the analysis here concentrates on short-term dynamics and not long-term equilibrium relationships between the variables.

Table 1: Unit root tests

Augmented Dickey-Fuller (ADF) Unit Root				
At Level				
	cpi	**mpi**	**er**	**Y**
With Constant	0.1774	0.535	0.316	0.968
With Constant & Trend	0.6481	0.369	0.742	0.724
Without Constant & Trend	0.8545	0.281	0.937	0.999
At First Difference				
	d(cpi)	**d(mpi)**	**d(er)**	**d(y)**
With Constant	0.073*	0.004***	0.000***	0.002***
With Constant & Trend	0.042**	0.021***	0.000***	0.013**
Without Constant & Trend	0.084*	0.000***	0.000***	0.005***
Unit root with Break test				
At Level				
	cpi	**mpi**	**er**	**Y**
Innovation Outlier	0.990	0.121	0.930	0.373
Additive Outlier	0.982	0.145	0.969	0.990
At First Difference				
	d(cpi)	**d(mpi)**	**d(er)**	**d(y)**
Innovation Outlier	0.010**	0.017**	0.000***	0.047**
Additive Outlier	0.012**	0.000***	0.001***	0.000***
Phillip-Perron (PP) Unit Root Test				
At Level				
	cpi	**mpi**	**er**	**Y**
With Constant	0.133	0.924	0.132	0.998
With Constant & Trend	0.931	0.586	0.580	0.678
Without Constant & Trend	0.995	0.999	0.976	1.000
At First Difference				
	d(cpi)	**d(mpi)**	**d(er)**	**d(y)**
With Constant	0.053*	0.000***	0.000***	0.003***
With Constant & Trend	0.027**	0.000***	0.000***	0.021**
Without Constant & Trend	0.096*	0.000***	0.000***	0.005***
Notes: Null Hypothesis: the variable has a unit root, (*) Significant at the 10%; (**) Significant at the				

- ✓ All the variables are non-stationary at levels in both the ADF, unit root with break and the PP unit root tests; the probability values of the test statistic fail to reject the null hypothesis of a unit root at the 5% level of significance.
- ✓ All variables are stationary at first difference, considering that the probability values of the test statistics reject the null hypothesis of a unit root at the 5% level or less in either the test with constant, with constant and trend or without constant and trend in both the ADF, unit root with break test and PP test.
- ✓ Hence, the data generation process of all the variables is of order I(1).

Following the common practice in the literature, the paper uses a first difference series for the estimation to avoid spurious regression.Under stationarity applications, the covariates have been presumed to be weakly exogenous with respect to the parameters of interest. With the assumption of exogeneity, the usual method of estimation is nonlinear least squares, and the asymptotic properties of the estimators as being discussed in Mira and Escribano (2000), Suarez-Fariñas et al. (2004), and Medeiros and Veiga (2005), among others. Nonlinear least squares (NLS) is equivalent to the quasi-maximum likelihood or, when the errors are Gaussian, with conditional maximum likelihood.

4.2 Empirical Results

4.2.1 Linear AR Model

The empirical analyses start with a baseline linear autoregressive (AR) model of the ERPT. The AR model is the linear part of the nonlinear STAR model in equation (4.1). The result of the linear AR model will be compared to the outcome of the nonlinear STAR models. The statistical test result of the coefficient of determination ($R^{2)}$, the sum of squared residuals (SSR) and Akaike Information Criterion (AIC) will be used to compare the performance of the two models. The linear AR model is as follows.

$$\Delta cpi_t = \beta_0 + \sum_{i=1}^{4} \beta_{1,i} \Delta cpi_{t-i} + \sum_{i=0}^{4} \beta_{2,i} \Delta mpi_{t-i} + \sum_{i=0}^{4} \beta_{3,i} \Delta y_{t-i} + \sum_{i=0}^{4} \beta_{4,i} \Delta e_{t-i} + \varepsilon_t \qquad (4.2)$$

Table 2, below presents the estimation result of the linear AR model in Equation (4.2) above.

Table 2: Linear AR Model

Variable	Coefficient	Std. Error	t-Statistic	p-values
Δcpi_t	0.8602	0.0501	17.1576	0.0000
Δe_t	0.0055	0.0237	0.2335	0.8159
Δmpi_t	-0.0039	0.1434	-0.0272	0.9784
Δy_t	-0.0992	0.1262	-0.7861	0.4336
β_0	0.0075	0.0039	1.9417	0.0549
R^2 = 0.75		SSR = 0.037		AIC = -5.046
LM-$\chi^2(1)$ = 0.34[0.55]			LM-F (1, 101) = 0.33[0.57]	
LM $_{ARCH}$(1) = 0.37[0.54]			LM $_{ARCH}$(2) = 0.41[0.66]	
JB = 838[0.00]				

R2 denotes the coefficient of determination, SSR is the sum of squared residuals, and AIC is the Akaike Information Criterion. LM-χ^2(1) and LM-F(1) are the first order chi-square and F-statistics Breusch-Godfrey Serial Correlation LM Test respectively. LM ARCH(1) and LM ARCH(2) are the first and second order F-statistics autoregressive conditional heteroscedasticity test respectively. JB is Jarque-Bera Normality test. Probability values are reported in the square brackets.

The diagnostic test shows that there is no serial correlation, as the first order Chi-square and F-statistics the Breusch-Godfrey Serial Correlation LM Test fails to reject the null hypothesis of no serial correlation. The result also indicates that residuals are homoscedastic as the autoregressive conditional heteroscedasticity test fails to reject null hypotheses of no heteroskedasticity. But, there is a non-normality problem as the Jarque-Bera normality test result shows rejection of the null hypothesis of normality.

The estimated result shows that the probability values of all the estimated coefficients except that of past inflation are not significant at 5% level, which implies that all variables except the past CPI inflation have no statistically significant effect on consumer price in Nigeria during the period 1986Q4 to 2013Q4 in the short run. The linear model does not show any impact of exchange rate change on the consumer prices in the short run, probably because the model could not capture the nonlinearities and the asymmetries. Hence nonlinear specifications are needed to capture the data generation prpcess.

4.2.2 Linearity Test

We begin by first testing the baseline AR model for linearity against smooth transition autoregression (STAR) nonlinearity. A suitable transition variable, from the potential ones, which results in strongest rejection of the null hypothesis of linearity is then included in the STAR model. However, economic intuition coupled with the sequence of null hypotheses is used in practice. The choice of the transition variable in this study is based on the potential ERPT asymmetry and/or nonlinearity which could be brought about by 1) the inflation environments in the economy (Taylor's Hypothesis), 2) disproportionate responses of the consumer prices to the direction and size of exchange rate changes, and 3) nonlinear response of price due to the stage of business cycle at which the ERPT takes place. Therefore, we choose inflation ($\Delta \boldsymbol{cpi}$), changes in the exchange rate ($\boldsymbol{\Delta e}$) and changes in output level ($\boldsymbol{\Delta y}$) as transition variables in separate estimations to identify the appropriate transition function (logistic or exponential STAR). With the choice of the three variables as the transition variables, the result will show the effect on the domestic consumer prices of the high inflation environment, changes in exchange rate and the output level in Nigeria during the period under review.

Table 3: Linearity test result

Transition Variable	H_0	H_4	H_3	H_2	Suggested Model
$\Delta \boldsymbol{cpi_t}$	0.0000	0.0000	0.55111	0.0000	LSTR
$\boldsymbol{\Delta e_t}$	0.0018	0.0453	0.2126	0.0029	LSTR
$\Delta \boldsymbol{mpi_t}$	0.0001	0.0056	0.1367	0.0018	LSTR
$\boldsymbol{\Delta y_t}$	0.9482	-	-	-	Linear

The H0 column shows the p-values of the test of linearity against the alternative of STAR nonlinearity. The H4, H3 and H2 columns are the p-values of the sequential test for choosing the appropriate transition function. The decision rule is as follows: If the test of H3 provides the strongest rejection of the null hypothesis, we choose the exponential STAR (ESTR) model; otherwise, we select the logistic STAR (LSTR) model. The last column reports the selected model.

The results in Table 3 above shows the presence nonlinearities in the variables as observed in the H_0 column all the potential transition variables except output growth ($\boldsymbol{\Delta y_t}$) have probability values significant at 5% level. As the linearity has been rejected, the sequence of nested null hypotheses is carried out to choose the appropriate transition function (logistic or exponential STAR). The chosen transition functions are report in the suggested model column in Table 3. However, the investigation for the effect of nonlinearities in the ERPT due to the size of the exchange change will be carried out by using an exponential transition function.

4.2.3 Nonlinear STAR Model Estimation Results

Following Nogueira Jr. and Leon-Ledesma (2011) and Cheikh (2012), the nonlinear STAR ERPT model presented in equation (4.1) was estimated. The estimation of the parameters of the STAR model was conducted using a nonlinear least squares (NLS) method. The suggested STR type to use while using consumer price inflation or the output gap as a transition variable is the logistic smooth transition regression (LSTR). When using the exchange rate as transition variable either of the LSTR or the exponential smooth transition regression (ESTR) could be adopted. The LSTR model can analyse asymmetric exchange rate pass-through with the currency appreciations and depreciations episodes. On the other hand, the ESTR is appropriate for examining nonlinearity in exchange rate pass-through due to the size of the change in the exchange rate (Nogueira Jr. and Leon-Ledesma, 2011). The models are tested for misspecification using tests of no remaining nonlinearity, parameters constancy, no error autocorrelation, no conditional heteroscedasticity and non-normality.

4.2.3.1 Consumer Price Inflation ($\Delta \mathbf{cpi_t}$) as Transition Variable

In this section, we investigate the Taylor's (2000) hypothesis in Nigeria, which asserts that a low inflation environment leads to a low ERPT and also generates nonlinearities in ERPT

The test results in Table 3 reject the null hypothesis of linearity and the LSTR model is suggested as the relevant specification for nonlinearities in the ERPT. Table 4, presents the results of the non-linear least squares estimation of the LSTR model. We first estimated the full LSTR model using least squares and a two-dimensional grid for the slope ($\boldsymbol{\gamma}$) and threshold ($\boldsymbol{c}$) variables as suggested in Van Dijk, Teräsvirta, and Franses (2002) to get reasonable starting values and then re-estimated the model using nonlinear least squares. The estimated LSTR model was checked using misspecification tests.

Table 4: Estimation result of LSTR model with CPI inflation (Δcpi_t) as transition variable

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Threshold Variables (linear part)				
Δcpi_{t-1}	0.8597	0.0267	32.165	0.0000
Δer_t	0.0244	0.0245	0.9970	0.3213
Δmpi_t	-0.0953	0.1227	-0.7768	0.4392
Δy_t	0.0771	0.0428	1.8023	0.0746
Threshold Variables (nonlinear part)				
Δcpi_{t-1}	-1.1395	0.0517	-22.057	0.0000
Δer_t	2.6491	0.1341	19.762	0.0000
Δmpi_t	14.741	0.3455	42.661	0.0000
Δy_t	0.7925	5.4669	0.1450	0.8850
Slopes				
Slope (γ)	210.97	50.879	4.1465	0.0001
Thresholds				
Threshold (c)	0.1296	0.0034	37.547	0.0000
R^2 = 0.9051	SSR = 0.0140	AIC = -5.9181		
LM-χ^2(1) = 0.15[0.70]	LM-F (1, 96) = 0.14[0.71]			
LM $_{ARCH}$(1) = 0.16[0.69]	LM $_{ARCH}$(2) = 0.17[0.84]			
JB = 0.27[0.21]				

R^2 denotes the coefficient of determination, SSR is the sum of squared residuals, and AIC is the Akaike Information Criterion. LM-χ^2(1) and LM-F(1) are the first order chi-square and F-statistics Breusch-Godfrey Serial Correlation LM Test respectively. LM ARCH(1) and LM ARCH(2) are the first and second order F-statistics autoregressive conditional heteroscedasticity test respectively. JB is Jarque-Bera Normality test. Probability values are reported in the square brackets.

The diagnostic test results presented in Table 4 above show no error autocorrelation in the disturbance as the probability value of the Chi-square and F-statistics Breusch-Godfrey serial correlation LM tests are both not significant at 5% level. There is also no ARCH effect, as the first and second order F-statistics of autoregressive conditional heteroscedasticity test have probability values statistically not significant at the 5% level. The Jarque-Bera test of normality also indicates normality. The result of parameter constancy and no remaining nonlinearity show rejection of the null hypotheses of no constant parameter and addictive nonlinearity (See Appendix 1).

The results in Table 4 shows a probability value significant at the 5% level for the threshold variable (c)[1] with 0.13 coefficient. This implies that inflation rate of 13 CPI points is estimated as the threshold level of inflation at which regime switching takes place. When inflation rates increase above the threshold of 13 CPI inflation points, the exchange rate transmission becomes higher (see Figure 1). The probability value of the speed of transition

[1] $c = (c_1, \dots, c_k)'$ is a vector of location parameters.

variable (γ) is also statistically significant at 5% level, and the coefficient is relatively moderate (210.97)[2], which is an indication of the smooth transition between the inflation regimes (see Figure 1).

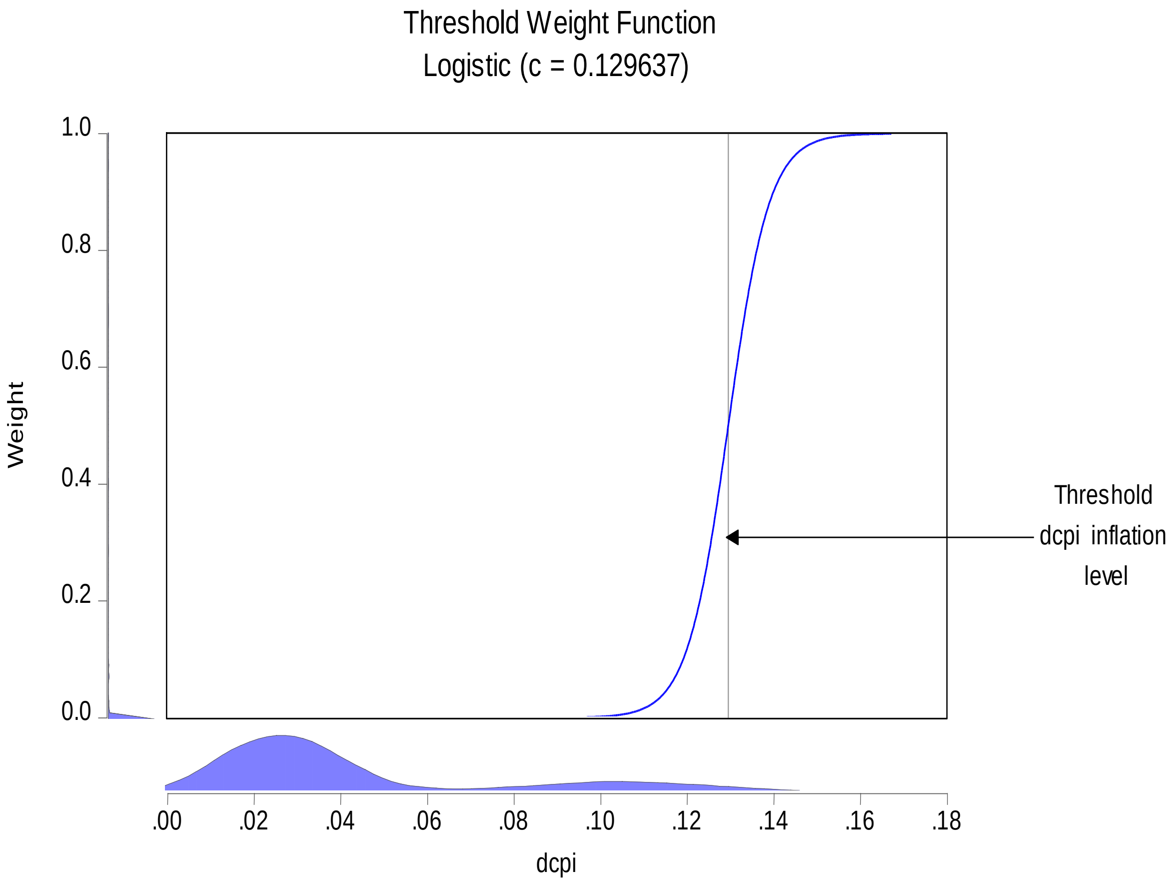
The results on the linear part of the STAR estimation presented in Table 4 reveal that no variable, except the past CPI-inflation (Δcpi_{t-1}) is statistically significant, and these results are similar to the linear AR model. However, results from the nonlinear part of the STAR estimation show that all variables except output growth are statistically significant. The coefficient of the exchange rate capturing the short-run nonlinear ERPT is highly statistically significant, supporting the presence and importance of the nonlinear short run ERPT in Nigeria when inflation exceeds the threshold.

Results of various diagnostics which include the coefficient of determination (R^2), the sum of squared residuals (SSR) and Akaike Information Criterion (AIC) reveal that the nonlinear STAR model outperforms the linear AR model. The nonlinear STAR model shows R^2 = 0.9051, SSR = 0.0140 and AIC = -5.9181 compared to that of the Linear AR model R^2 = 0.75, SSR = 0.037 and AIC = -5.046. These results are consistent with the fact that the potential causes of nonlinearities and asymmetries are evident in the pricing behaviors of importing firms in Nigeria.

Our results are consistent with Taylor's (2000) hypothesis which asserts that response of prices to changes in the exchange rate depends positively on the inflation environment. This result could be due to the importing firms' willingness to set prices in the currency of the importing country in the context of a stable inflation environment. Hence the ERPT will be lower with low inflation. However, when the firms perceive higher inflation, they switch from pricing with the importing country's currency to producer country pricing, which would generate a higher ERPT. Considering Nigeria's adoption of trade policies which removed trade restrictions and encourage international trade since 1986, it became easier for the importing firms in the country to switch between foreign and local inputs. These results corroborate the findings of Nogueira, Jr. and León-Ledesma, (2011), Shintani, Terada and Yabu (2013) and Cheikh (2012).

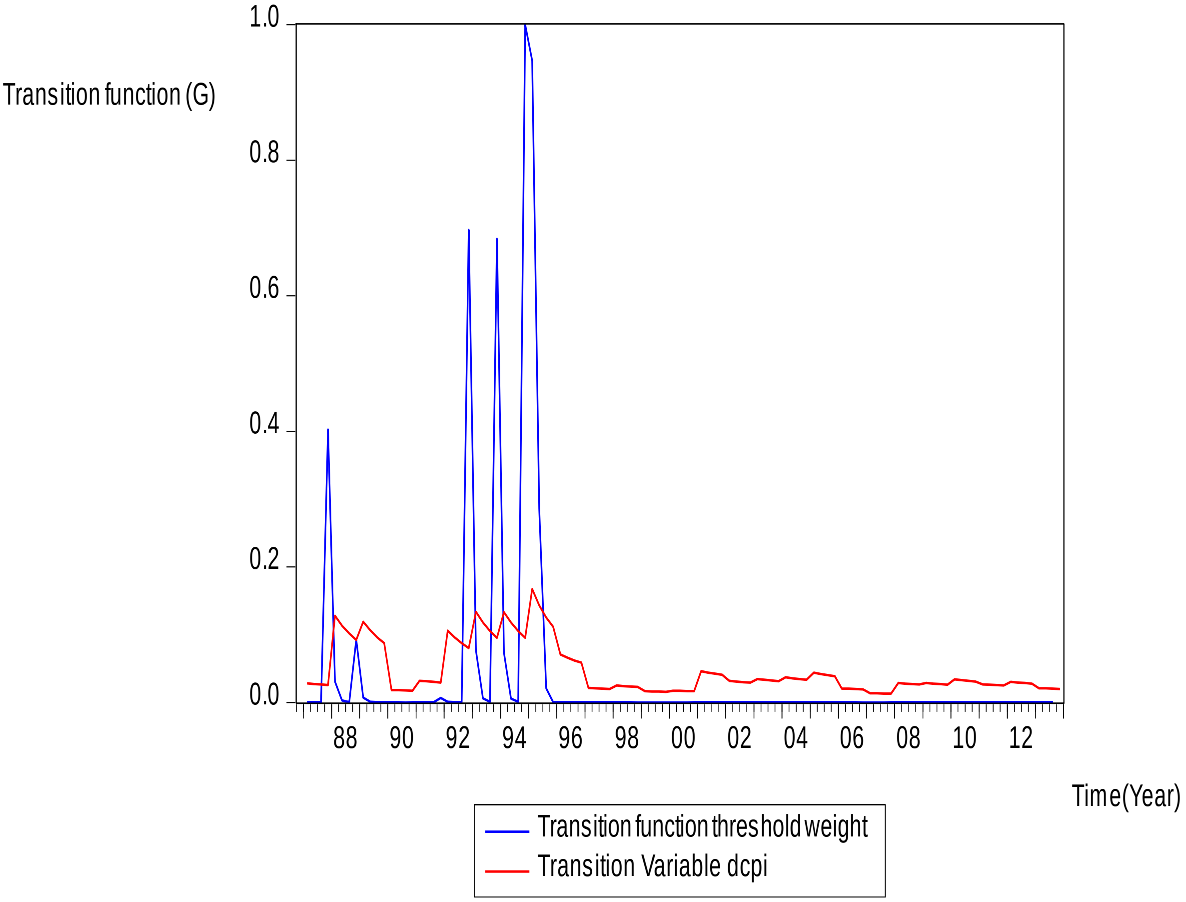
[2] The bigger the coefficient, the steeper the transition from one regime to the other becomes.

Figure 1: Estimated transition function as a function of past CPI inflation rates in Nigeria



The plot of the estimated transition function and the transition variable (CPI inflation) within our sample period shows clearly the inflation regime dependence of the exchange rate pass-through. However, it can be observed that the density of consumer price inflation is higher below the threshold level, where the nonlinearity is not prevalent. It can be observed from the Figure 2, below that the nonlinear ERPT was greater during higher inflation times of the late 1980s and the 1990s. The inflation rates exceeded the threshold during those periods, which leads to higher ERPT to the consumer price nonlinearly.

Figure 2: Plot of transition function and transition variable - CPI inflation (Δcpi_{t-i})



4.2.3.2 Exchange Rate Change (Δe_{t-i}) as Transition Variable

The change in the exchange rate ($\boldsymbol{\Delta e_{t-i}}$) is used in our analyses as a transition variable. As discussed earlier, the asymmetric ERPT is effective when consumer price responds disproportionately to appreciation and depreciation episodes of exchange rate changes. The logistic smooth transition regression (LSTR) specification is appropriate in modelling the situation in which the pass-through differs depending on whether the transition variable is below or above a certain threshold (Nogueira Jr. and Leon-Ledesma, 2011). Hence, the study uses the LSTR model to analyse asymmetries in the ERPT during currency appreciations and depreciations episodes, particularly where the threshold level of ($\boldsymbol{\Delta e_{t-i}}$) is close to zero.

The magnitudes of changes in exchange rate also generate nonlinearity in the ERPT. For example, a small change in the exchange rate is absorbed by the importing firms because of the menu costs, while big changes in the exchange rate are passed on to the consumers by an increase in prices. The ESTR specification is more relevant in modelling nonlinearity in the

ERPT due to size than the LSTR model (Nogueira Jr. and Leon-Ledesma, 2011). The empirical results in Table 3 show the presence of nonlinearity in the ERPT in Nigeria.

Hence this study examines the differential impact of the directions of exchange rate changes in generating asymmetry in the ERPT by applying LSTR to our data set. In addition, the differential impact of the magnitudes of exchange rate changes in causing nonlinearity in the ERPT is assessed by applying ESTR in Nigeria.

4.2.3.2.1 The Logistic STAR (LSTAR) model

The results from the LSTAR model which considers the change in the exchange rate ($\boldsymbol{\Delta e_{t-i}}$) as the factor causing asymmetric ERPT are reported in Table 5 below:

Table 5: Estimation result of the LSTR model with changes in the exchange rate (Δe_t) as transition variable

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Threshold Variables (linear part)				
Δcpi_t	0.9134	0.0580	15.7460	0.0000
Δe_t	-0.0005	0.0261	-0.0205	0.9837
Δmpi_t	0.1798	0.2378	0.7562	0.4514
Δy_t	-0.0214	0.1823	-0.1171	0.9070
Threshold Variables (nonlinear part)				
Δcpi_t	-0.0624	0.0846	-0.7375	0.4626
Δe_t	0.1412	0.0597	2.3627	0.0202
Δmpi_t	-0.1081	0.3161	-0.3420	0.7331
Δy_t	0.1411	0.2870	0.4917	0.6240
Slopes				
Slope (γ)	8663.496	70386.12	0.1230	0.9023
Thresholds				
Threshold (c)	0.0172	0.0013	13.141	0.0000
R^2 = 0.76	SSR = 0.036	AIC = -4.963		
LM-$\chi^2(1)$ = 1.16[0.28]	LM-F (1, 94) = 0.14[0.30]			
LM $_{ARCH}(1)$ = 0.17[0.68]	LM $_{ARCH}(2)$ = 0.32[0.72]			
JB = 64[0.12]				

R^2 denotes the coefficient of determination, SSR is the sum of squared residuals, AIC is the Akaike Information Criterion, LM-$\chi^2(1)$ and LM-F(1) are first order chi-square and F-statistics Breusch-Godfrey serial correlation LM test respectively. LM $_{ARCH}(1)$ and LM $_{ARCH}(2)$ are the first and second order F-statistics autoregressive conditional heteroscedasticity test respectively. JB is Jarque-Bera Normality test. Probability values are reported in the square brackets.

The diagnostic test results in Table 5 show no error autocorrelation is present in the disturbance, as the probability value of the chi-square and F-statistics Breusch-Godfrey serial correlation LM tests are both not statiscally significant at 5% level. There is also no ARCH effect indicated by statistically insignificant the first and second order F-statistics of autoregressive conditional heteroscedasticity tests. The Jarque-Bera test shows normality. The parameter constancy and no remaining nonlinearity tests results show rejection of the null hypotheses of no constant parameter and addictive nonlinearity (See Appendix 2).

The result of the nonlinear ERPT model estimation in Table 5 shows that probability value for the threshold variable (c) is statistically significant at 5% level with 0.017 coefficients. This implies that change in the exchange rate of 0.017 is the estimated threshold level of exchange rate change. When the exchange rate moves above the threshold of 0.017, exchange rate transmission becomes higher (see Figure 3). The probability value of the speed of transition variable (γ) appears insignificant. Because the estimate of γ could be quite imprecise and often turn out to be insignificant when evaluated by its t-statistic. This would still not be interpreted as an indication of weak nonlinearity, given that the t-statistic does not have its usual asymptotic t-distribution under the hypothesis that γ = 0, due to some identification problems. The coefficient of the γ is high (8663.5) which is an evidence of the more abrupt transition between the exchange rate regimes, as the transition becomes more steeper as the as the coefficient gets bigger (see Figure 3 below).

The linear part of the LSTR estimation presented in Table 5 shows no significant variable except the past CPI-inflation (Δcpi_{t-1}). However, the, nonlinear part of the estimation which captures the nonlinearity shows a probability values which is statistically significant at 5% level for the exchange rate ($\boldsymbol{\Delta e_t}$). This implies that there is a significant asymmetric ERPT to consumer prices in Nigeria during the sample period. The coefficient of the exchange rate ($\boldsymbol{\Delta e_t}$) variable shows the asymmetric ERPT in the short run. Movements in the exchange rate in Nigeria, which generally depreciates rather than appreciates during our sample period, create an asymmetric ERPT because importing firms generally respond reluctantly particularly during an appreciation episode as compared to a depreciation episode of the exchange rate.

It can also be observed from the depiction in Figure 4 below that as the exchange rate depreciates beyond a given threshold level (0.017), the ERPT becomes higher. Hence this implies that there is a greater ERPT with a higher rate of depreciation of the Naira, and a lower pass-through with small exchange rate depreciation and in appreciation episodes. This result is in line with the capacity constraints argument. As the quantity supplied by the importing firms is restricted due to their ability in the short run, they cannot increase sales as importing country’s currency exchange rate appreciates. Hence, they would allow the prices to increase by transmitting the exchange rate changes to the prices.

It can be observed that the nonlinear LSTR models provide a better fit to the data than the linear AR model considering the R-square and SSR. The LSTR model shows R^2 = 0.76, which is slightly higher than R^2 = 0.75 of the linear AR model. The LSTR model’s SSR and AIC are 0.036 and -4.963 respectively compared to that of the Linear AR model SSR = 0.037 and AIC = -5.046.

Figure 3: Estimated transition function (LSTR) as a function of exchange rate change

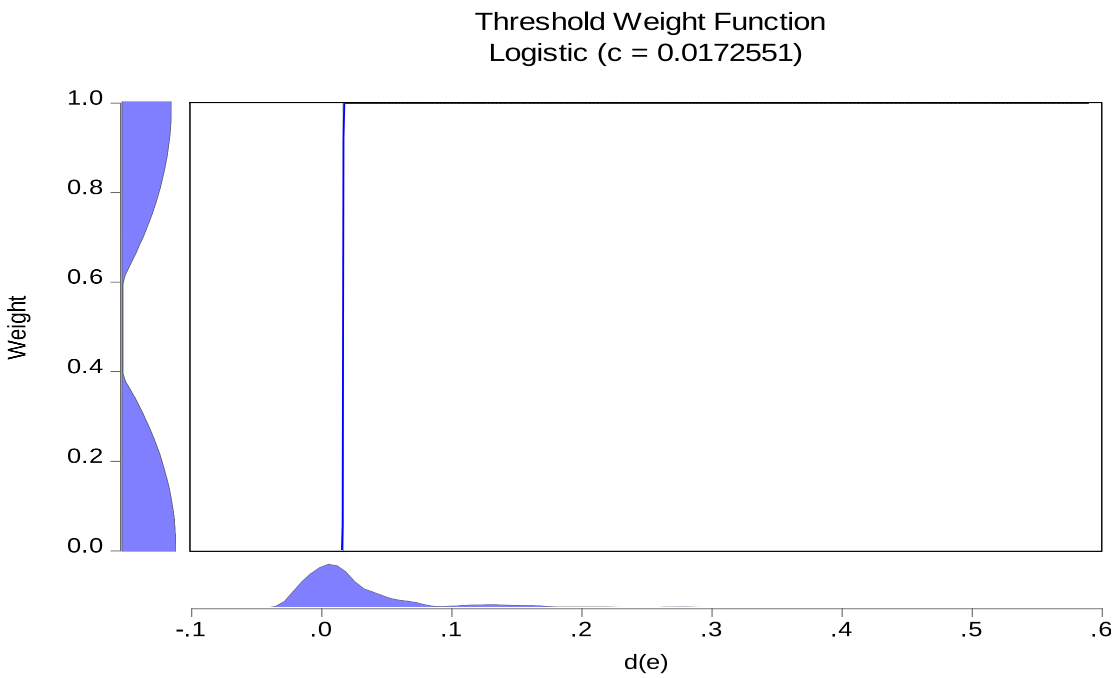
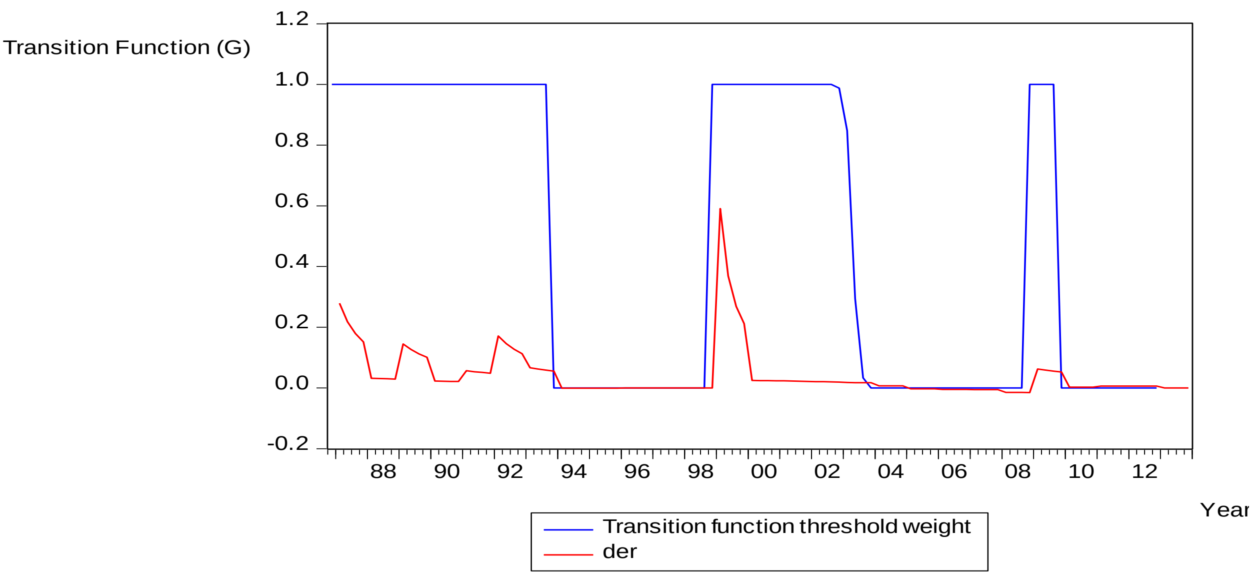


Figure 4: Plot of transition function (LSTR) and transition variable - exchange rate change (Δe_t)



4.2.3.2.2 Exponential STAR Model

To examine nonlinearity due to the size of the change in exchange rate, we used the ESTR model which is one of two types of the STAR model. Terasvirta (1994) suggests that the ESTR models are suitable when the local dynamic behavior of the process is: (a) similar when the transition variable is at its either lowest or highest level, (b) different if the transition variable is at its middle values. This feature of ESTR models enables it to capture potential nonlinearities in ERPT due to "menu costs", where firms only increase prices when exchange rate changes exceed a certain threshold. Therefore, the study used the ESTR model to examine the ERPT nonlinearity due to the size of the exchange change. Table 6 below presents the estimation result of the ESTR model.

Table 6: Estimation result of the ESTR model with changes in the exchange rate (Δe_t) as transition variable

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Threshold Variables (linear part)				
Δcpi_t	0.4494	0.1561	2.8780	0.0049
Δe_t	1.0334	0.2633	3.9242	0.0002
Δmpi_t	2.4670	0.7902	3.1219	0.0024
Δy_t	-1.0898	0.5052	-2.1568	0.0335
Threshold Variables (nonlinear part)				
Δcpi_t	0.5133	0.1674	3.0660	0.0028
Δe_t	-1.0931	0.2529	-4.3216	0.0000
Δmpi_t	-2.6281	0.8388	-3.1329	0.0023
Δy_t	1.2837	0.5707	2.2494	0.0268
Slopes				
Slope (γ)	124.4961	42.61864	2.921165	0.0044
Thresholds				
Threshold (c)	0.149599	0.009420	15.88108	0.0000
R^2 = 0.79	SSR = 0.031	AIC = -5.104		
LM-$\chi^2(1)$ = 0.00[0.99]	LM-F (1, 94) = 0.00[0.99]			
LM $_{ARCH}(1)$ = 0.026[0.87]	LM $_{ARCH}(2)$ = 0.16[0.85]			
JB = 48[0.32]				

R^2 denotes the coefficient of determination, SSR is the sum of squared residuals, AIC is the Akaike Information Criterion, LM-$\chi^2(1)$ and LM-F(1) are first order chi-square and F-statistics Breusch-Godfrey serial correlation LM test respectively. LM $_{ARCH}(1)$ and LM $_{ARCH}(2)$ are the first and second order F-statistics autoregressive conditional heteroscedasticity test respectively. JB is Jarque-Bera Normality test. Probability values are reported in the square brackets.

The diagnostic test results show that there are no misspecifications as the model passes all diagnostic tests (See Appendix 3).

The estimation results in Table 6 show the coefficient of the threshold (c) variable is 0.149 which is statistically significant at 5% level. These results suggest that when a change in the exchange rate exceeds the threshold level of 0.149, the ERPT will be higher. This is precisely depicted in Figure 5 below. The speed of transition variable (**γ**) also is statistically significant at the 5% level, and the coefficient (124) which is moderate and evidence of the smooth transition between the exchange rate regimes, as the transition between the regimes gets steeper as the coefficient gets bigger (see Figure 5).

The linear part of the ESTR estimation results in Table 6 shows that all variables are statistically significant at the 5% level. Likewise, the nonlinear part of the estimation results that all variables are statistically significant at the 5% level. Our variable of interest, the exchange rate ($\boldsymbol{\Delta e_t}$) in the table which represent the ERPT is significant in both the linear and not linear part. However, the sign of the coefficient is positive in the linear part, whereas in the nonlinear part it is negative. The sum of the linear and nonlinear part coefficients of the exchange rate is -0.0597 which is approximately zero.

The implication here is that nonlinear ERPT to consumer prices due to the size of exchange rate change in Nigeria in the short run was near zero in the sample period. The changes in the exchange rate in Nigeria during the sample period are predominantly below the threshold level (see Figure 7.5). Hence the pass-through was approximately zero, which does create a significant nonlinearity in the ERPT over the sample period.

Figures 7.6, depicts the nonlinearities due to the size of exchange rate change. The graph shows the size of exchange rate changes lead to approximately zero ERPT given that the density of the exchange rate changes is below the threshold. This result is consistent with the menu costs hypothesis. When the importing firms perceive that changing price changes would cost them more, they would be ready to absorb the small exchange rate in their mark-up. But when the change in exchange rate exceeds a given threshold, firms would be compelled to change their prices. Therefore, changes in exchange rate during the sample period (see Figure 7.5) which are mostly below the threshold level lead to a nonlinear ERPT in Nigeria during the sample period. Hence it is pertinent to recognise that if the exchange rate changes are smaller (below the threshold) the effect on consumer prices will be minimal or even zero.

The nonlinear LSTR models offer a better fit to the data than the linear AR models considering the R-square, SSR and AIC. The LSTR model shows R^2 = 0.76, SSR =0.031 and AIC = -5.104 while the linear AR model has R^2 = 0.75, SSR = 0.037 and AIC = -5.046.

Figure 5: Estimated transition function (ESTR) as a function of exchange rate change

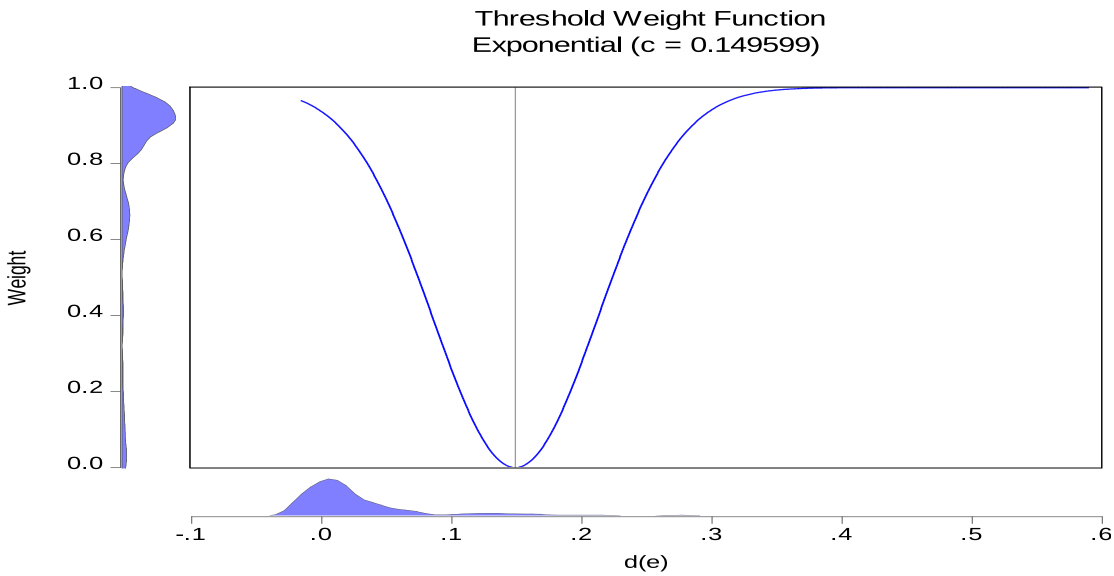
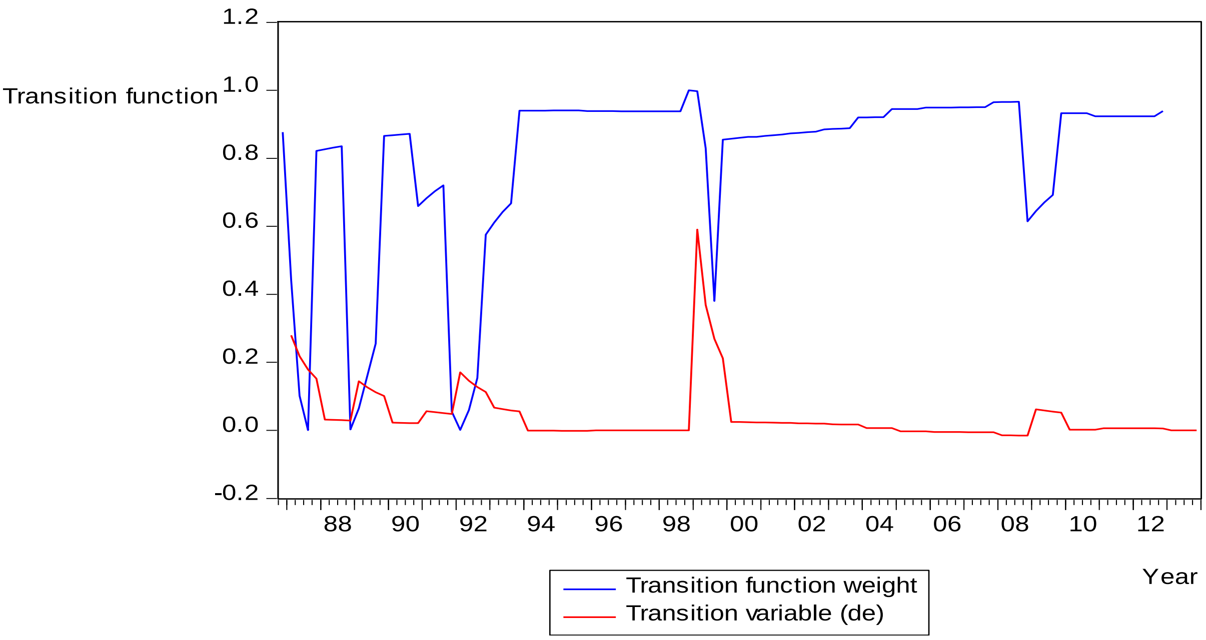


Figure 6: Plot of transition function (ESTR) and transition variable - exchange rate change (Δe_t)



4.2.3.3 Output level as a Transition variableAn output gap along with other factors may also influence the level of ERPT because it would be easier for firms to pass-through the effect of an exchange rate change during the economic boom than during the recession (based on Goldfajn and Werlang's (2000) and Garcia and Restrepo (2001)). For example, the low ERPT in a developing country like Chile in the 1990s was due to an adverse output gap which counterbalanced the inflationary effects of exchange rate depreciation. This study, therefore, has used the ERPT, taking changes in output level as our transition variable to determine if changes in output level cause nonlinearity in the ERPT. The linearity tests against STR nonlinearity carried out fail to reject the null of linearity for the sample period (See Appendix 4). The result hence implies that output gap changes do not lead to a nonlinear ERPT in Nigeria for our sample period.

5. Conclusion and Policy Recommendations

This paper has analyzed the role of asymmetries and nonlinearities in exchange rate pass-through (ERPT) into consumer inflation in Nigeria during the period 1986 to 2013 using various types of STAR models. We have examined the potential ERPT nonlinearities and asymmetries due to the inflationary environment in the economy, the size and direction of exchange rate change and output growth (changes in output level). The study develops a model in which an importing firm allows for a markup in its pricing policy. Based on this model, we have specified the empirical nonlinear ERPT model with smooth transition autoregression application.

The study confirms the presence of nonlinearity in the ERPT due to fluctuations in inflation levels in Nigeria in our sample period. Nonlinearity is more prevalent during the 1990s when the country experienced high inflationary preassures than in periods of low inflation. This study, therefore, confirms Taylor's (2000) hypothesis that pass-through declines in a low and stable inflation environment which creates a nonlinear ERPT. The policy implication of this result is the impact of exchange rate changes on consumer prices could be reduced by maintaining a low level of inflation.

This study examines the differential impact of the directions and magnitudes of exchange rate changes in causing nonlinearity in the ERPT in Nigeria. The results show an asymmetric ERPT to appreciations and depreciations of the exchange rates. The results also show nonlinearity with respect to the size of the exchange rate change. There is a greater ERPT with a higher rate of depreciation of the Naira; by contrast there is a lower ERPT with small exchange rate depreciations, and in appreciation episodes. These results are in line with the quantity constraint hypothesis, which asserts that the response of importing firms in transferring the change in the exchange rate to the consumer price is higher during periods of currency depreciation due to their capacity constants. The results also reveal that the magnitude of exchange rate changes generates differential impact and hence causes nonlinearity in the ERPT to prices. These results are in line with the menu cost hypothesis in which importing firms do not always transfer the exchange rate changes due to the cost of changing their menu. The effect of exchange rate changes on consumer prices is minimal when exchange rate changes are below the threshold level. Any policy in the country that will maintain the exchange rate movement below the threshold level would reduce the impact of exchange rate changes on domestic consumer prices.

The study also examined the role of output growth as a source of nonlinearities, a relationship which is not supported by our empirical results in the case of Nigeria.

The statistical test results indicate that the nonlinear STAR models fit the data better than the linear AR models in all cases. The study shows a significant nonlinear and asymmetric ERPT, even in the short-run. The linear models cannot capture the data generation process. It can be concluded that the ERPT is effective even in the short-run, though incomplete. The policy implication of our results on the monetary policy transmission mechanisms in the short run is that the effect of a monetary policy shock will be slow, given that the ERPT is incomplete. Hence, the international price adjustment role of a floating exchange rate regime of will not hold. Hence the authorities need to complement the monetary policy measures of controlling the exchange rate and price stability with other non-monetary measures.

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Appendix

Appendix 1: STAR model with CPI inflation as transition variable

Diagnostic Analysis of STAR Estimation

Smooth Threshold Linearity Tests

Sample: 1986Q4 2013Q4			
Included observations: 107			
Test for nonlinearity using DLCPI as the threshold variable			
Taylor series alternatives: b0 + b1*s [+ b2*s^2 + b3*s^3 + b4*s^4]			
Linearity Tests			
Null Hypothesis	F-statistic	d.f.	p-value
H04: b1=b2=b3=b4=0	20.76207	(16, 87)	0.0000
H03: b1=b2=b3=0	16.51295	(12, 91)	0.0000
H02: b1=b2=0	11.55762	(8, 95)	0.0000
H01: b1=0	11.72434	(4, 99)	0.0000
The H0i test uses the i-th order Taylor expansion (bj=0 for all j>i).			
Terasvirta Sequential Tests			
Null Hypothesis	F-statistic	d.f.	p-value
H3: b3=0	13.88397	(4, 91)	0.0000
H2: b2=0 | b3=0	8.050843	(4, 95)	0.0000
H1: b1=0 | b2=b3=0	11.72434	(4, 99)	0.0000
All tests are based on the third-order Taylor expansion (b4=0).			
The Linear model is rejected at the 5 percent level using H03.			
Recommended model: first-order logistic.			
. Pr(H3) <= Pr(H2) or Pr(H1) <= Pr(H2)			
Escribano-Jorda Tests			
Null Hypothesis	F-statistic	d.f.	p-value
H0L: b2=b4=0	13.80516	(8, 87)	0.0000
H0E: b1=b3=0	11.32768	(8, 87)	0.0000
All tests are based on the fourth-order Taylor expansion.			
The Linear model is rejected at the 5 percent level using H04.			
Recommended model: exponential with a nonzero threshold.			
. Pr(H0L) < Pr(H0E) with Pr(H0E) < .05			

Smooth Threshold Remaining Nonlinearity Tests

Additive nonlinearity tests using DLCPI as the threshold variable			
Taylor series alternatives: b0 + b1*s [+ b2*s^2 + b3*s^3 + b4*s^4]			
Additive Nonlinearity Tests			
Null Hypothesis	F-statistic	d.f.	p-value
H04: b1=b2=b3=b4=0	5.731647	(16, 81)	0.0000
H03: b1=b2=b3=0	6.521091	(12, 85)	0.0000
H02: b1=b2=0	5.083368	(8, 89)	0.0000
H01: b1=0	7.578786	(4, 93)	0.0000
The H0i test uses the i-th order Taylor expansion (bj=0 for all j>i).			
Terasvirta Sequential Tests			
Null Hypothesis	F-statistic	d.f.	p-value
H3: b3=0	6.763164	(4, 85)	0.0001
H2: b2=0 | b3=0	2.197576	(4, 89)	0.0756
H1: b1=0 | b2=b3=0	7.578786	(4, 93)	0.0000
All tests are based on the third-order Taylor expansion (b4=0).			
The original model is rejected at the 5 percent level using H03.			
Recommended model: first-order logistic.			
. Pr(H3) <= Pr(H2) or Pr(H1) <= Pr(H2)			

Smooth Threshold Parameter Constancy Test

Encapsulated nonlinearity test using trend as the threshold variable			
Taylor series alternatives: b0 + b1*s [+ b2*s^2 + b3*s^3 + b4*s^4]			
Parameter Constancy Tests			
Null Hypothesis	F-statistic	d.f.	p-value
H04: b1=b2=b3=b4=0	4.789292	(26, 71)	0.0000
H03: b1=b2=b3=0	4.339346	(23, 74)	0.0000
H02: b1=b2=0	4.834007	(16, 81)	0.0000
H01: b1=0	5.807807	(8, 89)	0.0000
The H0i test uses the i-th order Taylor expansion (bj=0 for all j>i).			

Appendix 2: LSTR model with change in the exchange rate as transition variable

Diagnostic Analysis of STAR Estimation

Smooth Threshold Linearity Tests

Null Hypothesis	F-statistic	d.f.	p-value
H04: b1=b2=b3=b4=0	4.259450	(16, 85)	0.0000
H03: b1=b2=b3=0	5.199410	(12, 89)	0.0000
H02: b1=b2=0	4.713613	(8, 93)	0.0001
H01: b1=0	0.527029	(4, 97)	0.7161
The H0i test uses the i-th order Taylor expansion (bj=0 for all j>i).			
Terasvirta Sequential Tests			
Null Hypothesis	F-statistic	d.f.	p-value
H3: b3=0	4.679194	(4, 89)	0.0018
H2: b2=0 | b3=0	8.732153	(4, 93)	0.0000
H1: b1=0 | b2=b3=0	0.527029	(4, 97)	0.7161
All tests are based on the third-order Taylor expansion (b4=0).			
The Linear model is rejected at the 5 percent level using H03.			
Recommended model: exponential.			
Pr(H2) < Pr(H3) and Pr(H2) < Pr(H1))			
Escribano-Jorda Tests			
Null Hypothesis	F-statistic	d.f.	p-value
H0L: b2=b4=0	1.906031	(8, 85)	0.0694
H0E: b1=b3=0	1.787588	(8, 85)	0.0907
All tests are based on the fourth-order Taylor expansion.			
The Linear model is rejected at the 5 percent level using H04.			
Recommended model: exponential with a nonzero threshold.			
. Pr(H0L) < Pr(H0E) with Pr(H0L) >= .05			

Smooth Threshold Remaining Nonlinearity Tests

Additive nonlinearity tests using DLER(-3) as the threshold variable			
Taylor series alternatives: b0 + b1*s [+ b2*s^2 + b3*s^3 + b4*s^4]			
Additive Nonlinearity Tests			
Null Hypothesis	F-statistic	d.f.	p-value
H04: b1=b2=b3=b4=0	3.918390	(16, 80)	0.0000
H03: b1=b2=b3=0	4.729385	(12, 84)	0.0000
H02: b1=b2=0	4.224149	(8, 88)	0.0003
H01: b1=0	2.383495	(4, 92)	0.0570
The H0i test uses the i-th order Taylor expansion (bj=0 for all j>i).			
Terasvirta Sequential Tests			
Null Hypothesis	F-statistic	d.f.	p-value
H3: b3=0	4.424719	(4, 84)	0.0027
H2: b2=0 | b3=0	5.589220	(4, 88)	0.0005
H1: b1=0 | b2=b3=0	2.383495	(4, 92)	0.0570
All tests are based on the third-order Taylor expansion (b4=0).			
The original model is rejected at the 5 percent level using H03.			
Recommended model: exponential.			
. Pr(H2) < Pr(H3) and Pr(H2) < Pr(H1))			
Escribano-Jorda Tests			
Null Hypothesis	F-statistic	d.f.	p-value
H0L: b2=b4=0	1.981621	(8, 80)	0.0593
H0E: b1=b3=0	1.347338	(8, 80)	0.2327
All tests are based on the fourth-order Taylor expansion.			
The original model is rejected at the 5 percent level using H04.			
Recommended model: exponential with a nonzero threshold.			
. Pr(H0L) < Pr(H0E) with Pr(H0L) >= .05			

Smooth Threshold Parameter Constancy Test

Parameter Constancy Tests			
Null Hypothesis	F-statistic	d.f.	p-value
H04: b1=b2=b3=b4=0	5.132103	(31, 65)	0.0000
H03: b1=b2=b3=0	3.194893	(23, 73)	0.0001
H02: b1=b2=0	1.219078	(15, 81)	0.2751
H01: b1=0	1.221889	(7, 89)	0.2993
The H0i test uses the i-th order Taylor expansion (bj=0 for all j>i).			

Appendix 3:ESTR model with change in the exchange rate as transition variable

Diagnostic Analysis of STAR Estimation:

Smooth Threshold Linearity Tests

Linearity Tests			
Null Hypothesis	F-statistic	d.f.	p-value
H04: b1=b2=b3=b4=0	4.259450	(16, 85)	0.0000
H03: b1=b2=b3=0	5.199410	(12, 89)	0.0000
H02: b1=b2=0	4.713613	(8, 93)	0.0001
H01: b1=0	0.527029	(4, 97)	0.7161
The H0i test uses the i-th order Taylor expansion (bj=0 for all j>i).			
Terasvirta Sequential Tests			
Null Hypothesis	F-statistic	d.f.	p-value
H3: b3=0	4.679194	(4, 89)	0.0018
H2: b2=0 | b3=0	8.732153	(4, 93)	0.0000
H1: b1=0 | b2=b3=0	0.527029	(4, 97)	0.7161
All tests are based on the third-order Taylor expansion (b4=0).			
The Linear model is rejected at the 5 percent level using H03.			
Recommended model: exponential.			
. Pr(H2) < Pr(H3) and Pr(H2) < Pr(H1))			
Escribano-Jorda Tests			
Null Hypothesis	F-statistic	d.f.	p-value
H0L: b2=b4=0	1.906031	(8, 85)	0.0694
H0E: b1=b3=0	1.787588	(8, 85)	0.0907
All tests are based on the fourth-order Taylor expansion.			
The Linear model is rejected at the 5 percent level using H04.			
Recommended model: exponential with a nonzero threshold.			
. Pr(H0L) < Pr(H0E) with Pr(H0L) >= .05			

Smooth Threshold Remaining Nonlinearity Tests

Additive Nonlinearity Tests			
Null Hypothesis	F-statistic	d.f.	p-value
H04: b1=b2=b3=b4=0	3.672866	(16, 79)	0.0001
H03: b1=b2=b3=0	3.460766	(12, 83)	0.0004
H02: b1=b2=0	4.625312	(8, 87)	0.0001
H01: b1=0	8.374209	(4, 91)	0.0000
The H0i test uses the i-th order Taylor expansion (bj=0 for all j>i).			
Terasvirta Sequential Tests			
Null Hypothesis	F-statistic	d.f.	p-value
H3: b3=0	1.092383	(4, 83)	0.3658
H2: b2=0 | b3=0	0.909667	(4, 87)	0.4621
H1: b1=0 | b2=b3=0	8.374209	(4, 91)	0.0000
All tests are based on the third-order Taylor expansion (b4=0).			
The original model is rejected at the 5 percent level using H03.			
Recommended model: first-order logistic.			
. Pr(H3) <= Pr(H2) or Pr(H1) <= Pr(H2)			
Escribano-Jorda Tests			
Null Hypothesis	F-statistic	d.f.	p-value
H0L: b2=b4=0	2.233742	(8, 79)	0.0333
H0E: b1=b3=0	2.231023	(8, 79)	0.0335
All tests are based on the fourth-order Taylor expansion.			
The original model is rejected at the 5 percent level using H04.			
Recommended model: exponential with a nonzero threshold.			
. Pr(H0L) < Pr(H0E) with Pr(H0E) < .05			

Smooth Threshold Parameter Constancy Test

Parameter Constancy Tests			
Null Hypothesis	F-statistic	d.f.	p-value
H04: b1=b2=b3=b4=0	2.792703	(32, 63)	0.0003
H03: b1=b2=b3=0	2.783625	(24, 71)	0.0005
H02: b1=b2=0	2.904434	(16, 79)	0.0009
H01: b1=0	0.933091	(8, 87)	0.4937
The H0i test uses the i-th order Taylor expansion (bj=0 for all j>i).			

Appendix 4: LSTR model with output growth(Δy_t) as transition variable

Test for nonlinearity using output growth(Δy_t) as the threshold variable

Linearity Tests			
Null Hypothesis	F-statistic	d.f.	p-value
H04: b1=b2=b3=b4=0	1.549236	(16, 87)	0.1010
H03: b1=b2=b3=0	1.807930	(12, 91)	0.0583
H02: b1=b2=0	2.007515	(8, 95)	0.0536
H01: b1=0	2.570625	(4, 99)	0.0425
The H0i test uses the i-th order Taylor expansion (bj=0 for all j>i).			
Terasvirta Sequential Tests			
Null Hypothesis	F-statistic	d.f.	p-value
H3: b3=0	1.349650	(4, 91)	0.2577
H2: b2=0 | b3=0	1.402592	(4, 95)	0.2390
H1: b1=0 | b2=b3=0	2.570625	(4, 99)	0.0425
All tests are based on the third-order Taylor expansion (b4=0).			
The Linear model is not rejected at the 5 percent level using H03.			
Escribano-Jorda Tests			
Null Hypothesis	F-statistic	d.f.	p-value
H0L: b2=b4=0	0.714619	(8, 87)	0.6780
H0E: b1=b3=0	0.746926	(8, 87)	0.6500
All tests are based on the fourth-order Taylor expansion.			
The Linear model is not rejected at the 5 percent level using H04.			