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Is Exchange Rate Pass-Through to Prices in Jamaica Non-Linear?

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Abstract

This paper establishes whether the pass-through of the exchange rate to the consumer price index (CPI) in Jamaica is non-linear using monthly data from 1996 to 2020. To explore the variation in exchange rate pass-through (ERPT) to inflation in different regimes, a threshold vector autoregression with exogenous variables (TVARX) was estimated. The TVARX allowed for the determination of a threshold value 'γ' that distinguishes between regimes of "low" and "high" depreciation. The results illustrate that the pass through of the exchange rate to core and headline inflation is non-linear. The estimated threshold values that separate the low depreciation from the high depreciation regimes for core and headline inflation are annual depreciation rates of 4.20 per cent and 7.40 per cent, respectively. The ERPT to headline inflation is estimated to be 0.4 percentage point during periods of low depreciation. The ERPT increases to 0.7 percentage point over 12 months during periods of high depreciation with complete pass through achieved within five quarters. For core inflation, the ERPT remains at 0.3 percentage point during periods of low and high depreciation 12 months after the shock.

JEL Classification Numbers: C32, E31, F31
Keywords: Exchange rate, Pass-through, Inflation, Threshold Vector Autoregression Model

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1 Introduction

This paper adds to the literature on the effects of the exchange rate on consumer prices in Jamaica. As a small open economy that is susceptible to shocks, the exchange rate plays a key role in the price determination process and the transmission mechanism of monetary policy. Against this background, the purpose of this paper is to establish whether there is a non-linear pass-through of the exchange rate to consumer prices in Jamaica using data from 1996 to 2020.

Exchange rate pass-through (ERPT) to consumer prices is estimated using a threshold vector autoregressive model with exogenous variables (TVARX). Unlike a linear VAR, this methodology allows us to identify if there are different pass-through coefficients depending on the rate of adjustment of the exchange rate.[1] The pass-through is estimated on headline inflation (calculated as the year-on-year change in the overall consumer price index (CPI) compiled by the Statistical Institute of Jamaica) and core inflation (which excludes agricultural food and fuel prices) and selected sub-divisions of the CPI.[2] This approach is taken to identify how the ERPT varies across the selected divisions and sub-divisions of the CPI basket. Consistent with the literature, our a priori expectation is that components of the CPI basket with a higher import content will display a higher ERPT. Previous seminal studies on exchange rate pass-through to headline inflation for Jamaica used linear methodologies.[3] This paper adds to the literature by accounting for non-linearity as well as estimating the ERPT on the sub-components of the CPI as well as on core inflation.

There is evidence of non-linearities in the ERPT to consumer prices. We estimate that the ERPT to core and headline inflation is incomplete over the 12-to-24-month horizons in the low depreciation regime.[4] In the high depreciation regime, the time to complete (i.e. 100% pass through to prices) ranges from 1.3 years (approximately 5 quarters) to 4 years for headline and core inflation, respectively. The estimated threshold values that separate the low depreciation from the high depreciation regimes for core and headline inflation are annual depreciation rates of 4.20 per cent

[1] See Jorge A. Jaramillo (2018)
[2] Since headline inflation includes the rate of change for commodities such as agricultural food and energy prices, it tends to be more volatile than core inflation.
[3] See Robinson (1998) and McFarlane (2002).
[4] The extent and speed of pass-through has been proven to differ across time. Studies on exchange rate pass through to inflation tend to select monthly data frequencies and assess pass-through over a 12-month and 24-month window, which is deemed adequate for price reactions from changes in the exchange rate. For example, Kohlscheen (2010), Miyajima (2019), and Jaramillo (2018) examined the ERPT to inflation over 12- and 24-month span and found that inflation reacts differently across the time periods.

and 7.40 per cent, respectively. For selected divisions and sub-divisions of the CPI basket, the exchange rate threshold that separates periods of low and high depreciation ranges from 0.88 per cent to 7.01 per cent.

During periods of low depreciation, we find that an increase of 1.0 per cent in the pace of depreciation results in a 0.40 percentage point increase in headline inflation 12 months after the shock. During periods of high depreciation, the impact of an increase of 1.0 per cent in the pace of depreciation on headline inflation rises to 0.70 percentage point. For core inflation, the ERPT remains at 0.3 percentage point during periods of low and high depreciation 12 months after the shock.

The paper is organized as follows: Section 2 summarizes the literature on exchange rates and the pass-through to prices, whilst section 3 outlines the methodology. Data description and stylized facts are outlined in section 4 while section 5 presents the results. Section 6 concludes.

2 Literature Review

According to Goldberg (1996), exchange rate pass-through refers to "the percentage change in local currency import prices resulting from a one per cent change in the exchange rate." Techniques to estimate the pass-through can either be based on linear or non-linear methodologies. Typically, linear models (for example ordinary least squares (OLS)) are known for their easy implementation. Given that OLS estimators have standard asymptotic properties, it is possible to test linear restrictions, either in one equation or across equations with the standard T- and F-statistics. On the other hand, non-linear/threshold regression models are efficient in identifying structural breaks in the coefficients during different regimes, which linear models assume away.

Jaramillo (2018) highlighted that while most of the literature rely on linear approaches to estimate ERPT, there is a growing strand of the literature (particularly in emerging markets) that accounts for non-linearities. Non-linearities are present when inflation responds differently to exchange rate variations implying that the ERPT changes based on shifts in the exchange rate regime (low depreciation, high depreciation, appreciation etc.). Ghartey (2018) argued that empirical studies which examine the exchange rate pass-through to inflation via OLS, often yield results which suffer from serial correlation, heteroscedasticity and functional-form instability problems. This stemmed from his observation that since some central banks apply monetary policy differently when exchange rates are outside their designated zones, linear models do not sufficiently fit the data generating process. In this regard, he examined the non-linearities in exchange rate pass-through and monetary policy principles for six Caribbean countries (Jamaica, Barbados, Guyana, Belize, The Bahamas, and Trinidad & Tobago). In an attempt to resolve the linearity bias problem, he used the threshold autoregressive (TAR) analysis as well as the momentum threshold autoregressive (MTAR). The estimated threshold model had the following specification:

$$P_t = \mathrm{b}_1 rtbr_t + b_2 rxr_t + b_3 wpsp_t + b_4 fp_t + c + u_t$$

Where *P*, *rtbr*, *rxr*, *wpsp* and *fp* are logarithmic form of consumer price index (CPI), real Treasury bills rates (RTBR), real effective exchange rates (RXR), world petroleum spot prices (WPSP), and foreign prices (FP), respectively. The F-statistics was assessed to determine whether the adjustments are symmetrical or asymmetrical. The author defined the threshold variable and its associated values and assessed whether the adjustment towards long-run equilibrium is symmetrical. The results from the various tests revealed that depreciation had a higher pass-through to prices than an appreciation, especially during inflationary periods. The TAR results depicted asymmetric adjustments towards long-run equilibrium for The Bahamas, Guyana, and Jamaica (to a lesser extent) and symmetrical adjustments in Barbados, Belize and Trinidad & Tobago. The MTAR results confirmed asymmetric adjustment in four countries, while Guyana and Trinidad & Tobago experienced symmetric adjustments.

Non-linear ERPT may result from downward rigidities in prices, binding capacity constraints, market share strategies, menu costs, the choice of invoicing currency, the state of the business cycle or the level and variability of inflation (Colavecchio, 2020). For example, when the exchange rate appreciates, producers rarely reduce retail prices due to price stickiness. Similarly, firms may wait until changes in the exchange rate are large enough before adjusting prices to limit menu costs. In addition to previous explanations of asymmetric pass-through, Maka (2013) argued that the expectation of market participants also contributes to asymmetric pass-through. He found that due to Ghana’s historical trend of continuous depreciation, firms are less likely to change prices in periods of appreciation than they would for depreciation. For that reason, in periods of extended depreciation, firms are expected to increase their prices to make up for any loss arising from adverse movements in the exchange rate. Similarly, he highlighted that domestic importers will not reduce prices during periods of appreciation because of the expectation of future depreciation.

Not all studies found higher pass-through during periods of depreciation. Khundrakpam (2007) found that while ERPT during periods of appreciation in India was 0.20 per cent, it declined to 0.05 per cent for depreciation. Under India's inward-looking strategy of industrialization, most goods were produced domestically irrespective of quality. After liberalization, foreign exporters faced competition from locally produced substitutes and as such were more willing to pass on the benefit of lower prices from appreciation to domestic consumers to capture a larger market share rather than pass on the higher prices to consumers from depreciation and lose market share. In this context, the pass-through to prices from appreciation would be higher than that of depreciation due to competition. Similar conclusions were reached by Wickremasinghe (2004) and Mihaljek (2008). Wickremasinghe (2004) examined the exchange rate pass-through to import prices for manufactured goods in Japan using asymmetric unit root tests. He found evidence of an asymmetric pass-through with appreciation being passed through more strongly than depreciation to import prices. Mihaljek (2008) revealed that while exchange rate depreciations have a significant and stronger effect on domestic inflation than appreciations in some countries, there were few countries where the reverse holds true.

With regard to the size of the ERPT, Tunc (2017) in his study proffered that a high degree of openness leads to higher competition in the domestic economy resulting in "pricing to market" which lowered the ERPT to domestic prices. For small economies, however, Ghosh (2013) claimed a positive impact of openness on the size of the exchange rate pass-through. Therefore, the more open a country is, the larger the size of the ERPT to prices.

3. Methodology

3.1 TVARX Model

Following Bruneau (2015) we employ a Threshold Vector Autoregressive methodology (TVARX).[5] The TVARX, which is an extension of linear VARX models, is typically applied to multivariate time series data when there is evidence of regime switching behaviour. In contrast to

[5]VARX models allow for exogenous variables to be added to the VAR framework. The unrestricted TVARX model was estimated by sequential conditional ordinary least squares (equivalent to maximum likelihood) using the Bruneau (2015) codes in MATLAB R2021a.

a linear VAR, the TVARX approach allows us to identify whether there are different coefficients of pass-through for varying degrees of depreciation of the exchange rate. The TVARX framework also allows us to include exogenous variables in the model. As highlighted earlier, we anticipate that there will be a different pass-through to prices during periods of low relative to high depreciation. Thus, we model the exchange rate depreciation as our threshold variable.

We estimate a two regime TVARX model with the following specification:

$$y_t = \begin{cases} A_1(L)y_t + B_1(L)x_t + \varepsilon_{1t} \;\; if\ (E_{t-d} \leq \gamma) \\ A_2(L)y_t + \; B_2(L)x_t + \varepsilon_{2t} \;\; if\ (E_{t-d} > \gamma) \end{cases}$$

where:

Y_t: {D_CPI , D_CORE$_t$, D_CPI COMPONENTS$_t$,D_EX_t,}

X_t: {D_USCPI$_t$, D_WTI$_t$}

Where y_t is a vector of the endogenous variables at time 't'. $A_1$and A_2 are polynomial matrices, x_t is a vector of exogenous variables at time 't', with B being their respective matrix of coefficients. L is the lag operator. The optimal lag order is determined by the Akaike Information Criteria (AIC). E represents the threshold variable at lag order d (the delay parameter). Since γ is known, the model reduces to an OLS on two distinct samples. Therefore, γ represents the threshold that distinguishes between the "low" depreciation and "high" depreciation regimes.[6] ε_t are structural disturbances.

3.2 Asymmetric Impulse Response

Given the possibility of a threshold effect, the application of an impulse response function (IRF) analysis may not capture non-linearities. IRFs are derived from linear VARs that are estimated with coefficients that are constant through time. As such, linear IRFs will show symmetry irrespective of the sign and magnitude of the shocks. According to Koop et al. (1996) the effect of a shock depends on the entire history of the system up to the point when the shock occurs. Hence, it is necessary to model the VAR conditional on this history, and subsequently, conditional on the size and the direction (sign) of the shock. Moreover, since the IRF does not depend on a particular history of the data up to time t, we compute instead the generalized impulse response functions (GIRF) introduced

[6] The threshold γ is endogenously determined by using the maximum likelihood estimation. $\hat{\gamma}$ maximizes the likelihood function.

by Koop et al. (1996). The GIRF addresses the problems that apply to both linear and non-linear models.

Koop et al. (1996) define the GIRF as the difference between two conditional expectations driven by a single exogenous shock:

$$GIR = [X_{t+m} | \varepsilon_{t+1} = 0, \ldots \ldots \varepsilon_{t+m} = 0, \Omega_{t-1} - [X_{t+m}| = 0,$$

$$\varepsilon_{t+1} = 0, \ldots\ldots + m = 0, \Omega_{t-1}]$$

For this paper the GIRF is characterized as follows:

$$(k, V_t, \Omega_{t-1}) = [Y_{t+k} | V_t, \Omega_{t-1}] - E[Y_{t+k} | \Omega_{t-1}]$$

The GIRF for variable Y is derived as the difference between the simulated VAR k periods ahead, conditional to certain history ($\Omega t{-}1$) with shock (Vt) and the simulated VAR conditional only on the history $\Omega t{-}1$. For the confidence bands, we follow the common approach for TVAR systems such as Schmidt (2019). Further details on the computation of the GIRFs and confidence bands are shown in the Appendix under GIRFs Algorithms.

3.3 Pass-Through Estimation

To provide a better understanding and interpretation of the degree of the ERPT, the pass-through coefficient is calculated from the GIRF for inflation and the exchange rate. Particularly, we compute the ratio of the accumulated GIRF of inflation to the accumulated GIRF of the exchange rate for the 12-month and 24-month time horizons. This represents the cumulative elasticity of each price index with respect to the exchange rate shock. The accumulated ERPT elasticity 'T' periods after a shock that took place at time 't' is defined as:

$$\varepsilon_t = \frac{\Delta\% P_{t,t+T}}{\Delta\% NER_{t,t+T}}$$

Where $\Delta\%P_{t,\, t+T}$ is the cumulative percentage change of the price level T periods after the shock and $\Delta\%NER_{t,\, t+T}$ is the percentage change of the exchange rate in the same period. The elasticity can be interpreted as the change in price in percentage points given a one percentage point exchange rate depreciation. Since the accumulated GIRF is used, the elasticity denotes the average for the period.

3.4 Model Diagnostics

The robustness of the forecast accuracy of the TVARX model is assessed via a three-step procedure. First, the response data is divided into three periods: pre-sample, estimation and prediction or forecast. Second, the model is fitted to the estimation data using the pre-sample period to provide lagged data. Finally, a Monte-Carlo simulation is performed with a specified number of sample paths by estimating the predicted or forecasted values of the fitted models to the observations using goodness-of-fit measures.

Diagnostic tests were employed to test the stability of the VAR models. The results showed that there were no evidence of serial correlation, heteroscedasticity and autoregressive conditional heteroscedasticity effect in the disturbances (see Table 1). Further, the estimated VAR models are stable as the inverted roots of the model for each variable lie inside the unit circle (see Figure 1).

4. Data and Stylized Facts

We employed monthly time series data for the period 1996:01-2020:12. The data consists of 300 observations for the following endogenous variables: core inflation (D_CORE), headline inflation (D_CPI), seven sub-components of headline inflation Cereal & Cereal Products (D_C_CP), Meat (D_Meat), Milk & Other Dairy Products (D_M_ODP), Non-Alcoholic Beverages (D_NAB), Alcoholic Beverages & Tobacco (D_ABT), Electricity, Gas & Other Fuels (D_EGOF), and Restaurants & Accommodation (D_REST_ACCOM)) and the exchange rate depreciation (D_EX) (see Table 2).[7] The exogenous variables include US inflation (D_US_CPI) and West Texas Intermediate (D_WTI) oil prices. [8] [9]

[7] To control for demand, a series on monthly real electricity sales (which is correlated with GDP) was included, however, it proved to be insignificant and hence was excluded from the final version of the model.
[8] Core inflation is defined as headline inflation less agricultural food and fuel prices.
[9] Previous research on Jamaica's aggregate supply curve indicates that US CPI has a direct impact on import prices while

The paper incorporated the measure of core inflation due to the volatility of headline inflation.[10] Within the Jamaican CPI basket, 73.3 per cent of the items are classified as core items and 26.7 per cent as non-core.[11] Within the non-core items, agricultural food items and fuel related items (transport, electricity, gas & other fuels) contribute 9.6 per cent and 17.1 per cent, respectively. Given that agricultural food and fuel items can be volatile due to external factors that are outside of the control of the local authorities, they can induce excess volatility in headline inflation irrespective of their size in the basket hence the importance of understanding the ERPT for both inflation measure.

The Augmented Dickey- Fuller (ADF) test was computed to test the variables for the presence of unit-roots. The ADF test indicated that most of the variables were non-stationary in levels, in that the null hypothesis of the presence of a unit root could not be rejected for most of the time series. Testing the variables for the presence of a unit root on their first differences indicated that the time series were stationary, therefore we concluded that the variables were integrated of order one I(1) (see and Table 3 Appendix). All variables are expressed as the annual logarithmic difference $\Delta_{12}ln$, written as (D_*variable name*). In addition, the dataset is examined for multicollinearity, heteroscedasticity, and correlation (see Tables 4, 5, & 6, Appendix). The LM test showed no serial correlation up to lag 3, the Variance Inflation Factor test revealed that there is no severe multicollinearity in the dataset, while the Breusch-Pagan-Godfrey test showed that the framework is free from heteroscedasticity.

The correlation matrix (see Table 6, Appendix), illustrated a weak but positive correlation between D_CPI and D_EX with a 0.05 correlation coefficient. D_CORE reflected a similar result as D_EX with a correlation coefficient of 0.12. Notwithstanding the weak contemporaneous correlation between the exchange rate depreciation and inflation, movements in the exchange rate impact changes in consumer prices in Jamaica. The sub-components correlation matrix (see Table 7, Appendix) illustrated a strong positive relationship among inflation sub-components.

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changes in the WTI has both a direct and indirect impact on import prices. The latter reflects adjustments to real marginal costs of producers consistent with the high import intensity of production in Jamaica.

[10] For the period January 2001 to December 2020, the standard deviation for core inflation is 4.3 while for headline inflation it is 4.9.

[11] Bank of Jamaica classification.

5. Results

The results showed that the threshold values for exchange rate depreciation in relation to core and headline inflation were a depreciation rate of 4.20 per cent and 7.40 per cent, respectively (see Table 8, Appendix). However, for the selected divisions and sub-divisions the threshold values ranged from 0.88 per cent to 7.01 per cent. This means that when the exchange rate depreciates above or below these rates, we observe a different degree of pass-through. Rates of change in the exchange rate which rise above the threshold values represent periods of "high" depreciation, while changes below represent episodes of "low" depreciation.

Similar to the work done by Jaramillo (2018) and Ghartey (2018) the results revealed that the pass-through for headline inflation, along with some of the inflation divisions and sub-divisions were higher during periods of high depreciation than during periods of low depreciation. These results, which were obtained through the TVARX procedure are represented in Table 9, Appendix. The results revealed that for every 1.0 percentage point increase in depreciation above the threshold value of 4.20 per cent, core inflation increased by 0.3 percentage point 12 months after the shock. The pass-through of an additional depreciation of 1.0 per cent above the threshold of 7.40 per cent raised headline inflation by 0.70 percentage point. In the low depreciation environment, however, the pass-through to core inflation remains constant over 12 months, while the ERPT to headline inflation falls to 0.4 percentage point. Abstracting from agriculture and fuel prices (i.e. using core CPI) the pass-through remained the same for both the low and high depreciation periods. Some components of the CPI basket displayed a higher pass-through in the low depreciation environment than in the environment of high depreciation. At most, two lags were appropriate to describe the dynamics of the system.

Figure 2, Appendix depicts the exchange rate and the threshold values for core and headline inflation. There were fewer periods of low depreciation than high depreciation in the data set. Approximately 80 per cent of the data represented periods of high depreciation while the remaining 20 per cent depicted periods of low depreciation. The highest rates of depreciation were recorded in December 2002, January 2007, December 2009 and April 2012. Three unprecedented years of low depreciation/appreciation in the Jamaican currency occurred in 1996, 2010 and 2018.

A possible reason for the higher ERPT to headline inflation relative to core inflation is that headline inflation includes the impact of changes in the prices of electricity, gas and other fuels which have higher import intensity. In addition, for the electricity sub-component, the country's sole electricity provider follows a pricing rule that is used to calculate electricity bills.[12] This rule includes a customer charge, an energy rate, a fuel charge (this covers the cost of the fuel required to produce and deliver each kWh of electricity), an Independent Power Producer (IPP) charge, a demand charge and a foreign exchange (FX) adjustment.[13,14] The fuel charge changes monthly, depending on the cost of the fuel (both oil and natural gas). Because oil is imported and used to produce fuel, changes in the exchange rate indirectly impacts the rate charged for electricity. The inclusion of an FX adjustment also results in a direct pass through. Each month the change in the exchange rate is applied to bills via a threshold mechanism. If the exchange rate is above this threshold (i.e. the base exchange rate set by regulators), the adjustments will result in a higher bill and vice versa. The Housing, Water, Electricity, Gas and Other Fuels division of the CPI basket, which consists of the Electricity, Gas and Other Fuels sub-division, has the second highest weight in the CPI basket.

In regard to the inflation sub-divisions, Alcoholic Beverages & Tobacco (ABT) and Electricity, Gas & Other Fuels (EGOF) recorded a higher pass-through for periods of high depreciation than periods of low depreciation (see Table 9, Appendix). During periods of low depreciation, the pass-through for the ABT and EGOF divisions are 0.40 percentage point and 0.50 percentage point, respectively, while for periods of high depreciation the pass-through are 1.40 percentage point (implying some degree of overshooting) and 0.90 percentage point, respectively.[15]

There is empirical evidence in the literature to support an overshoot, whereby the exchange rate pass-through to local prices is above one. Studies illustrate that the ERPT can overshoot due to threshold pricing, the firm's market structure, and elasticity of demand for the particular good or service.[16] For instance, firms with significant market power (like monopolies) tend to have a higher pass-through than firms in more competitive industries.[17] Robert Cooter (1981) attributed this

[12] The Jamaica Public Service Company Limited (JPS) is an integrated electric utility company and the sole entity licensed to transmit, distribute and supply electricity in Jamaica. JPS also purchases power from a number of IPPs.
[13] Customer charge is a fixed monthly fee to cover the cost of meters, meter maintenance, bill delivery, inter alia. The energy rate is the non-fuel charge for producing and delivering each kilowatt-hour (kWh) of electricity consumers consume.
[14] The energy rate is the non-fuel charge for producing and delivering each kilowatt-hour (kWh) of electricity consumed. Total energy charges depend on how much electricity is consumed for each period.
[15] For this paper, overshooting is defined as a pass-through to prices that is greater than one.
[16] Threshold pricing is the process by which retailers adjust prices in discrete intervals consistent with some pre-determined price point or threshold, rather than using a proportional markup relative to cost.
[17] In a perfectly competitive market, price equals marginal cost and firms earn an economic profit of zero. In a monopoly,

variance to factor substitution, whereby monopolies overcharge if the price of one factor of production rises and the substitution process to switch to other factors whose prices have not changed is difficult.[18] Consequently, consumer prices will increase proportionately more relative to the increase in production costs to compensate for this higher price. In other words, monopolies will increase consumer prices above cost resulting in a pass-through higher than one. Cooter (1981) concluded that the extent of the pass-through will depend entirely on the ability of producers to substitute against the overcharged factor.

The monopolistic structure of the alcohol and tobacco industries in Jamaica coupled with the highly inelastic demand for these products support a stronger than proportional ERPT for this subcomponent of the CPI basket (see Table 9, Appendix). Additionally, the threshold pricing approach typically adopted for cigarettes, serves as another channel through which higher ERPT may occur. Notably, the extent of overshooting associated with threshold pricing is larger for goods and services at lower price points, such as cigarettes. Therefore, a rise in price will have a pass-through greater than one in a non-competitive market structure with inelastic low-priced items.

Considering a 24-month window, the pass-through to headline inflation increases to 0.60 percentage point in the low depreciation regime, relative to 0.40 percentage point over 12 months. The pass-through to core inflation increases to 0.70 percentage point over 24 months relative to 0.30 percentage point over twelve months (see Table 9).[19] This implies an incomplete pass through during periods of low depreciation for both headline and core inflation over two years (see Figures 3 & 4, Appendix). Based on the cumulated impulse response, the time to achieve a complete pass through, ranges from between three to five years for core inflation within the high depreciation regime. This protracted lag may reflect the impact of expectations and menu costs which may induce friction in price setting behavior.

It is clear that while the results illustrate non-linear exchange pass-through, they are mixed. While headline inflation and a few of the inflation sub-divisions have a lower ERPT in an environment of

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the price is set above marginal cost and the firm earns a positive economic profit.

[18] Overcharge/overshift refers to industries raising prices much more than the initial increase in cost. In other words, having a pass-through greater than one.

[19] See Figures 5,6,7 & 8 (Appendix) for the impulse responses for headline and core inflation in the different depreciation regimes, respectively.

low depreciation than during periods of high depreciation, the Non-Alcoholic Beverages division exhibits a lower pass-through within an environment of high depreciation and a higher pass-through within an environment of low depreciation for both the 12 and 24-month windows. The ERPT may be lower during periods of high depreciation in cases where imported goods face close domestic substitutes. If there are domestic substitutes for a particular good that has a high import content, the pass-through will be lower as consumers can easily switch to the good's closest substitutes. This may be the case for non-alcoholic beverages (see Table 9, Appendix).[20] The inflation sub-divisions with higher pass-through in the high depreciation regime on the other hand, reflect downward price rigidity. The results also reveal that depreciation is passed-through more strongly 24 months after the shock, than after 12 months. This may reflect the impact of menu costs which may induce friction in price setting behavior.

6. Conclusion

The aim of the paper is to test the presence of non-linearity of the ERPT to inflation. We employed a TVARX estimation that allowed us to identify the presence of asymmetric responses of inflation to exchange rate movements. The model uses monthly time series data for the period 1996:01 to 2020:12 and estimated non-linear pass-through coefficients for core and headline inflation, along with other inflation divisions and sub-divisions from the CPI basket. The results indicate that the pass-through differ depending on whether the economy is facing an environment of "low" depreciation or "high" depreciation. These regimes are distinguished using an average level of exchange rate depreciation (a threshold level determined endogenously).

While in an environment of low depreciation, core and headline inflation increases by 0.30 and 0.40 percentage point, respectively. The threshold values for core and headline inflation were estimated at 4.20 per cent and 7.40 per cent, respectively. When the economy is facing an environment of high depreciation (i.e., above the respective threshold value), the pass-through of a one per cent shock to the exchange rate raises core and headline inflation by 0.30 and 0.70 percentage point respectively, 12 months after the shock. These results can be used to improve the Bank's inflation forecasting models as well as its understanding of the transmission mechanism of monetary policy.

[20] However, the overshooting of the ERPT for non-alcoholic beverages within the low depreciation regime remains a puzzle and is left for future work.

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Appendix

Table 1: Vector Autoregressive Stability Tests

VAR Stability Tests*			
1.VAR Residual Serial Correlation LM Tests			
Null hypothesis: No serial correlation at lag h			
Lag	LRE* stat	Prob.	
1	22.99079	0.114	
2	21.44796	0.1619	
3	13.04773	0.6693	
*Edgeworth expansion corrected likelihood ratio statistic.			
2. Heteroskedasticity Test: Breusch-Pagan-Godfrey			
Null hypothesis: Homoskedasticity			
F-statistic		Prob. F (3,226)	0.2437
Obs*R-squared	4.195327	Prob. Chi-Square (3)	0.2411
3. Heteroskedasticity Test: ARCH			
Null hypothesis: No heteroscedasticity			
F-statistic	1.974112	Prob. F (1,227)	0.1614
Obs*R-squared	1.974335	Prob. Chi-Square (1)	0.16

* MacKinnon (1996) one-sided p-values.

Figure 1: Autoregressive Roots Graph

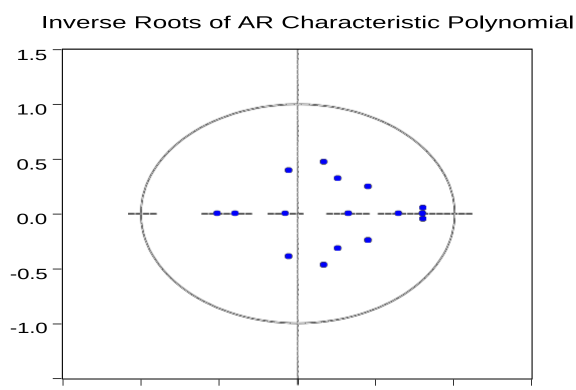


Table 2: Descriptive Statistics[21]

Variables	Variables Notation	Mean	Maximum	Minimum	Std. Dev.
CORE Inflation	D_CORE	1.4370	5.4807	-4.4308	0.9944
Headline Inflation	D_CPI	0.9230	5.6051	-2.6460	1.0416
Cereals & Cereal Products	D_C_CP	9.0244	45.1925	0.7691	8.4357
Meat	D_MEAT	8.9698	21.2306	2.0336	5.1909
Milk & Other Dairy products	D_M_ODP	9.6354	27.1119	1.3231	5.8999
Non-Alcoholic Beverages	D_NAB	7.7300	74.4197	-51.3257	12.2616
Alcoholic Beverages & Tobacco	D_ABT	9.9560	32.6957	1.0434	8.2297
Electricity, Gas & Other Fuels	D_EGOF	9.9889	42.0442	-27.1502	12.5600
Restaurants & Accommodation	D_REST_ACCOM	6.0712	14.4002	0.4549	3.6046
Exchange rate depreciation	D_EX	6.4229	24.9364	-4.4730	6.5407
WTI	D_WTI	-0.0785	43.6128	-44.1473	13.4325
US CPI	D_US_CPI	0.3662	2.4000	-4.1480	0.8191

Table 3: Augmented Dickey-Fuller Unit Root Test

	Variables at Level (P-Values) *		Variables at 1st difference (P-Values) *	
Variable	**With Constant**	**Constant & Trend**	**With Constant**	**Constant & Trend**
CORE	0.84	0.37	0.00	0.00
CPI	0.37	1.44	0.00	0.00
D_C_CP	0.94	0.84	0.00	0.00
D_MEAT	0.99	0.40	0.00	0.00
D_M_ODP	0.98	0.67	0.00	0.00
D_NAB	0.95	0.11	0.00	0.00
D_ABT	0.97	0.79	0.00	0.00
D_EGOF	0.94	0.31	0.00	0.00
D_REST_ACCOM	0.97	0.91	0.00	0.00
D_EX	0.01	0.03	0.00	0.00
WTI_OIL	0.01	0.28	0.00	0.00
US_CPI	0.20	0.20	0.00	0.00

* MacKinnon (1996) one-sided p-values.

[21] All variables are expressed as the annual logarithmic difference $\Delta 12ln$, written as (D_variable name)

Table 4: Multicollinearity Test

Variance Inflation Factors*			
Variable	**Coefficient Variance**	**Uncentered VIF**	**Centered VIF**
C	0.010512	2.370559	NA
XR_DEPR	1.09E-04	2.074784	1.009621
D_US_CPI	0.007225	1.278953	1.05432
D_WTI_OIL	0.000156	1.049527	1.048734

*If VIF < 10, the model is free from multicollinearity

Table 5: Heteroskedasticity Test

Heteroskedasticity Test: Breusch-Pagan-Godfrey

Null hypothesis: Homoskedasticity

F-statistic	1.432471	Prob. F (4,225)	0.2241
Obs*R-squared	5.711758	Prob. Chi-Square (4)	0.2217
Scaled explained SS	15.94089	Prob. Chi-Square (4)	0.0031

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.741725	0.228213	3.250137	0.0013
D_CORE	-0.005983	0.119273	-0.05016	0.96
XR_DEPR	0.003501	0.01831	0.191193	0.8485
D_US_CPI	-0.054102	0.149514	-0.36185	0.7178
D_WTI_OIL	-0.048486	0.021773	-2.22689	0.0269

* If p>0.05, accept the null hypothesis

Table 6: Correlation Matrix

	D_CORE	**D_CPI**	**XR_DEPR**	**D_US_CPI**	**D_WTI_PRICES**
D_CORE	1.000	0.535	0.119	0.127	0.186
D_CPI	0.535	1.000	0.051	0.166	0.230
XR_DEPR	0.119	0.051	1.000	-0.081	-0.219
D_US_CPI	0.127	0.166	-0.081	1.000	0.261
D_WTI_OIL	0.186	0.230	-0.219	0.261	1.000

Table 7: Correlation Matrix: Inflation Sub-Components

	D_C_CP	D_MEAT	D_M_ODP	D_NAB	D_ABT	D_EGOF	D_REST_ACCOM
D_C_CP	1.000	0.997	0.992	0.985	0.996	0.973	0.997
D_MEAT	0.997	1.000	0.996	0.990	0.997	0.972	0.997
D_M_ODP	0.992	0.996	1.000	0.992	0.993	0.956	0.991
D_NAB	0.985	0.990	0.992	1.000	0.989	0.956	0.987
D_ABT	0.996	0.997	0.993	0.989	1.000	0.968	0.995
D_EGOF	0.973	0.972	0.956	0.956	0.968	1.000	0.973
D_REST_ACCOM	0.997	0.997	0.991	0.987	0.995	0.973	1.000

Table 8: Estimated Thresholds

Inflation	Exchange Rate Threshold
Core	4.20%
Headline	7.40%
Cereals & Cereal Products	3.90%
Meat	7.01%
Milk & Other Dairy products	0.88%
Non-Alcoholic Beverages	6.06%
Alcoholic Beverages & Tobacco	6.06%
Electricity, Gas & Other Fuels	5.75%
Restaurants & Accommodation	1.96%

Table 9: Exchange Rate Pass-through

	12 Month		24 Month		Time to complete ERPT in	
Inflation	High Depreciation Regime	Low Depreciation Regime	High Depreciation Regime	Low Depreciation Regime	Low Depreciation Regime	High Depreciation Regime
Core	0.3	0.3	0.5	0.7	-	3.9
Headline	0.7	0.4	1.4	0.6	-	1.3
Cereals & Cereal Products	0.3	0.0	0.4	0.0	-	-
Meat	0.4	0.2	0.5	0.4	-	-
Milk & Other Dairy products	0.4	0.3	0.6	0.3	-	-
Non-Alcoholic Beverages	0.3	1.3	0.5	1.5	0.6	-
Alcoholic Beverages &	1.4	0.4	1.7	0.7	-	0.6
Electricity, Gas & Other Fuels	0.9	0.5	1.0	0.5	-	1.5
Restaurants & Accommodation	0.1	0.1	0.2	0.2	-	-

Figure 2: Exchange Rate Threshold for Core and Headline Inflation

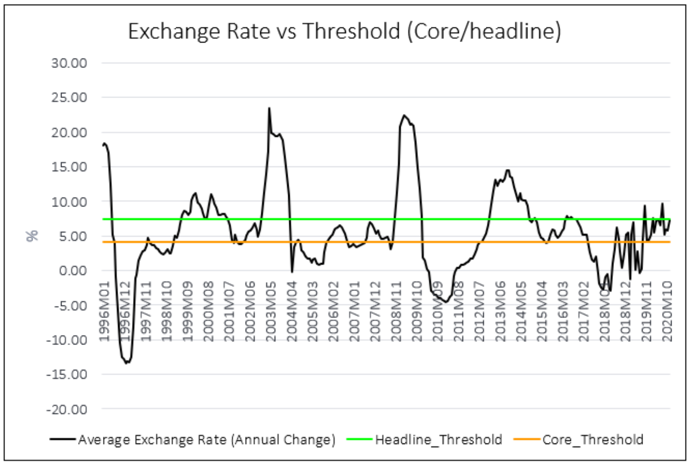
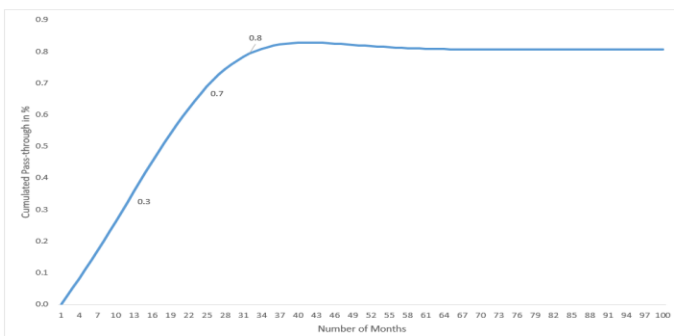


Figure 3: Cumulated Exchange Rate Pass-Through to Core Inflation in the Low and High Depreciation Regimes

Low Depreciation Regime



High Depreciation Regime

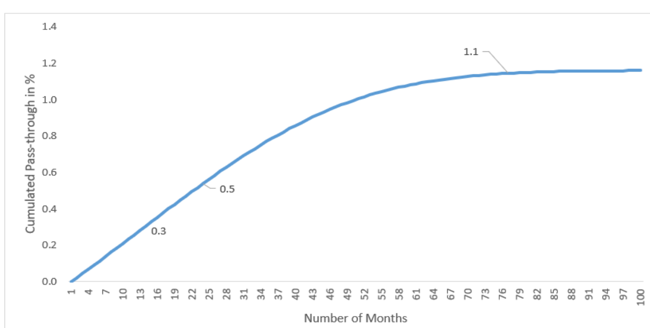
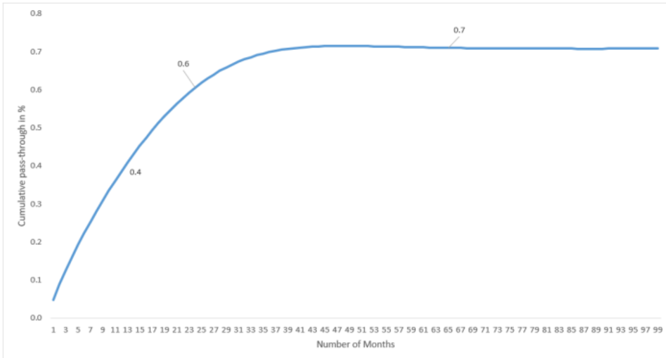


Figure 4: Cumulated Exchange Rate Pass-Through to Headline Inflation in the Low and High Depreciation Regimes

Low Depreciation Regime



High Depreciation Regime

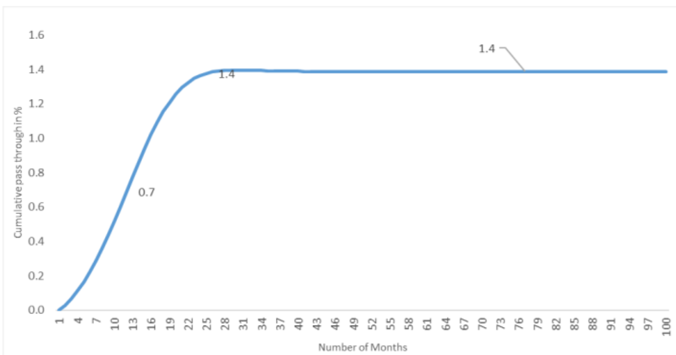


Figure 5: Impulse Responses in the High Depreciation Regime (Headline Inflation)[22]

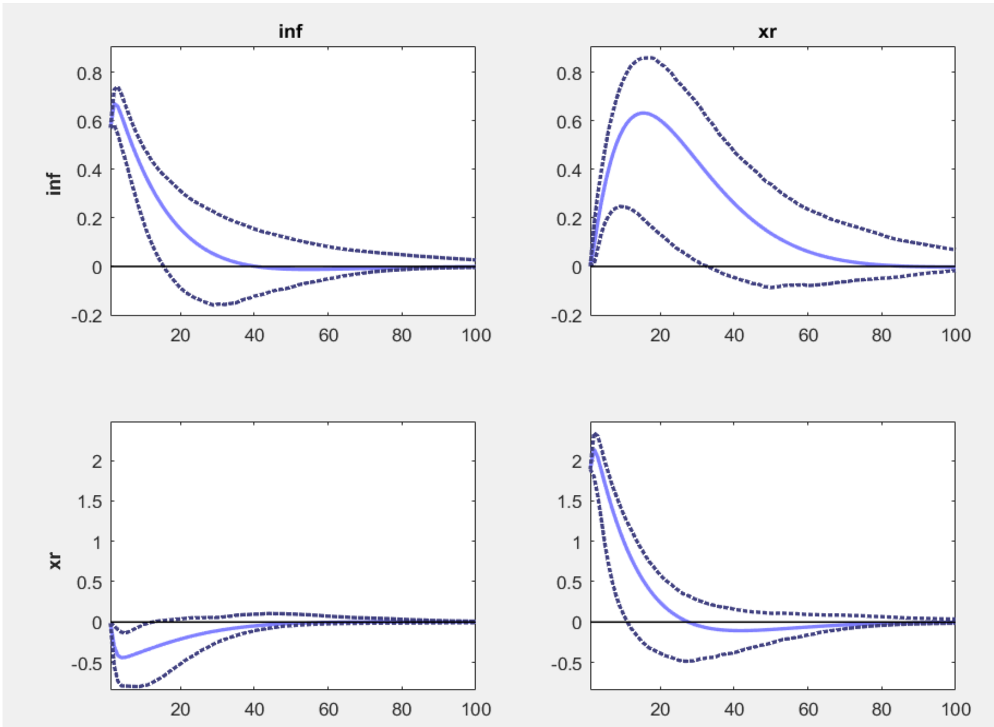
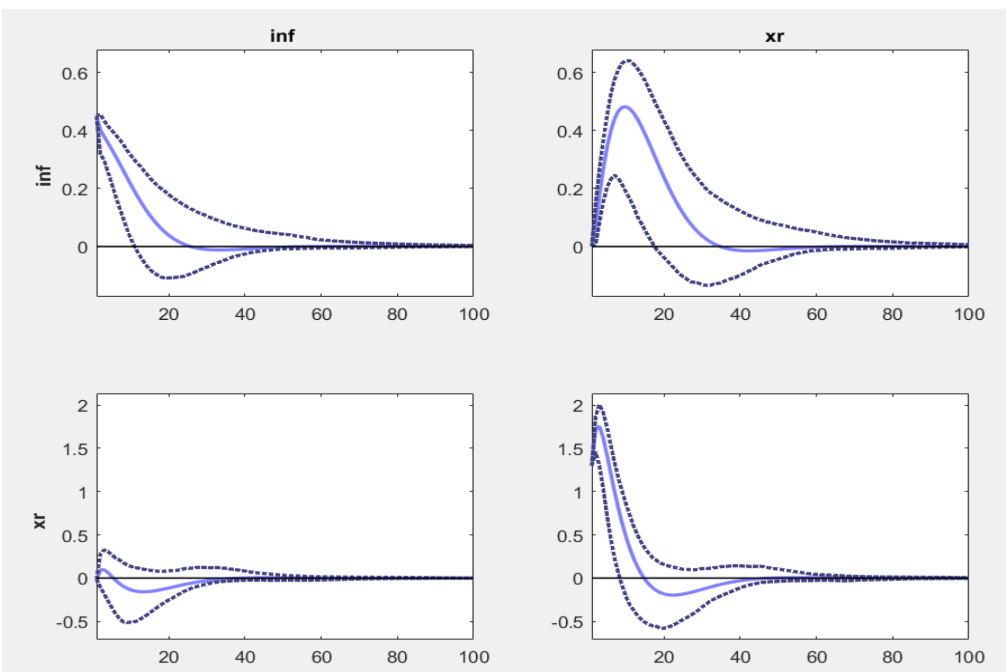


Figure 6: Impulse Responses in the Low Depreciation Regime (Headline Inflation)



[22] Low and High Depreciation Regimes are classified as regime 1 and regime 2, respectively.

Figure 7: Impulse Responses in the High Depreciation Regime (Core Inflation)

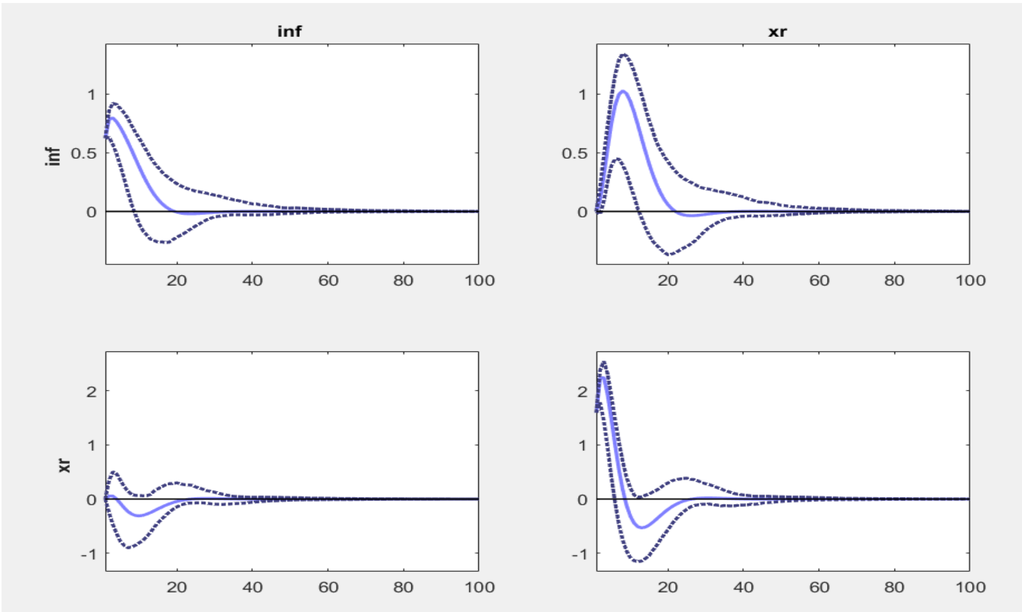
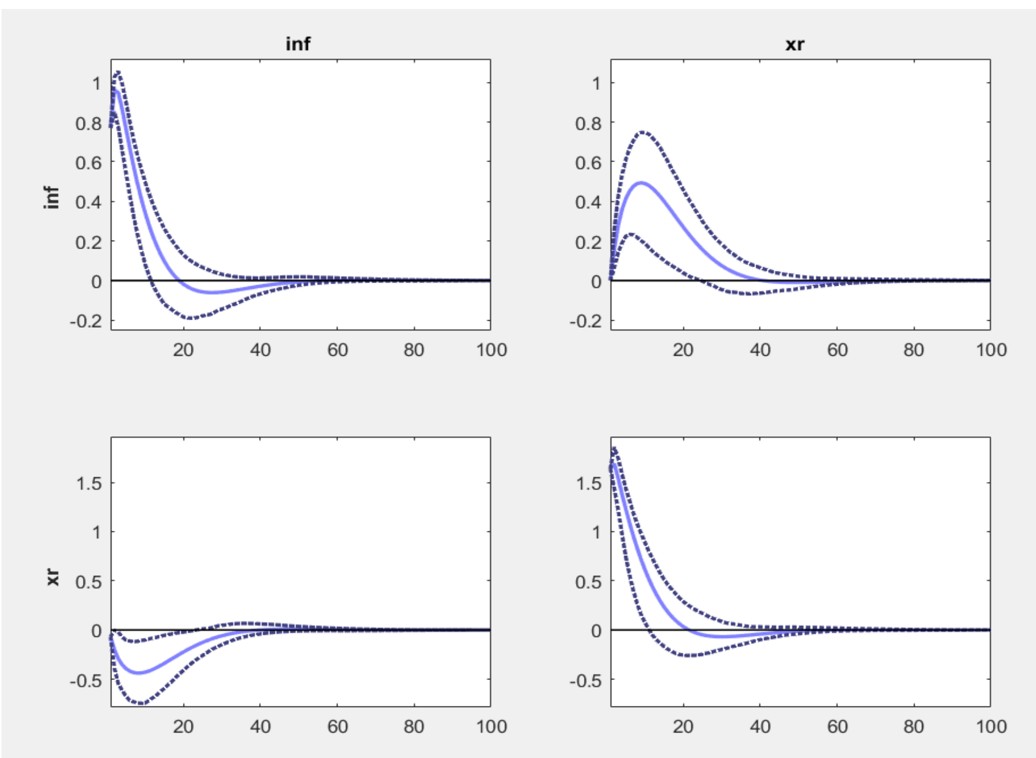


Figure 8: Impulse Responses in the Low Depreciation Regime (Core Inflation)



GIRFs Algorithm

GIRFs are computed following the algorithm in Baum and Koester (2011). This procedure was used by Schmidt (2019) and Ferraresi et al. (2013).

1. Select a history Ω^{r}_{t-1}. A history is chosen for each regime, so we repeat the algorithm twice.
2. Through bootstrap sampling, shocks are drawn based on the matrix of variance- covariance of the residuals.
3. The history Ω^{r}_{t-1} is used along with the shocks to simulate the evolution of the model.
4. Repeat Step 3 and add a new shock.
5. Steps 2 to 4 are repeated B times.
6. Take the average over the difference of the B estimates of the two paths.
7. Repeat steps 1 to 6 over all possible histories.
8. Compute the average GIRF, which is the difference between the simulated forecast and the forecast without a particular shock.

Compute confidence bands following the algorithm in Schmidt (2019).

1. Artificial data is generated recursively using the estimated coefficients and errors from the TVAR structure.
2. Using the recursive data set, the regression coefficients, as well as error terms, are estimated from a TVAR assuming the threshold corresponds to the estimated value.
3. Using the original data set, but the coefficients and errors from step 2, GIRFs are estimated as described in the above algorithm for each particular combination of shocks and initial conditions.
4. Steps 1 to 3 are repeated S times to generate a sample distribution of the GIRFs from which confidence bands are drawn at the respective significance levels.