Estimating monetary policy rules in small very open economies*

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Abstract

This paper presents an approach for empirically estimating long-run monetary policy rules in small *very* open economies. The cointegrated VAR methodology is applied to the case of Trinidad and Tobago. Long-run analysis reveals an empirically accepted long-run monetary policy rule among the domestic and foreign interest rate differential, the exchange rate, domestic, foreign and oil prices and a regime dummy for the zero lower-bound monetary policy regime. It also provides empirical evidence that oil price shocks are transmitted through the TT economy in part via the effects on US prices. Short-run analysis reveals a specification for the nominal exchange rate with significant adjustment to the estimated monetary policy rule and significant effects from foreign and domestic variables save for the exchange rate. Parameter estimates of the parsimonious VEqCM are empirically constant and produce reliable forecasts.

JEL codes: C51, C52, E52, E58, F31, F41

Key words: Cointegration, exogeneity, Fisher open parity, monetary policy, PPP, small very open economies, Trinidad and Tobago, UIP.

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1 Introduction

This paper presents an approach for empirically estimating hypothesized monetary policy rules for small very open economies.[1] The hypothesized policy rules focus on the spread between domestic and foreign short-term interest rates, measures of the economy's ability to earn foreign exchange and the exchange rate among other domestic and foreign variables. These policy rules may appear quite different from those of large closed or small open economies that focus on the long-run relation among short and long-term interest rates and other domestic variables. The difference is mainly due to marked reliance of these economies to earn valuable foreign exchange and attract international investment, say in the form of FDI. The case of Trinidad and Tobago is investigated as it is clearly a small very open economy and also fits the bill of both a small island developing state (SIDS) and small non-renewable natural resource economy (SNRNRE).

The paper makes several contributions to understanding how monetary policy is conducted in small very open economies. First, it estimates an empirically accepted long-run monetary policy rule for TT among the domestic and foreign interest rate differential, the exchange rate, domestic, foreign and oil prices and a regime dummy for the zero lower-bound monetary policy regime. Second, it provides empirical evidence that oil price shocks are transmitted through the TT economy in part via the effects on US prices. Third, it identifies a dynamic short run specification for the TTD/USD nominal exchange rate. Notably, the exchange rate specification is not autocorrelated, however, it does depend significantly on the estimated monetary policy rule, foreign and domestic prices and interest rates and oil prices. Fourth, empirically long-run weak exogeneity is not rejected for domestic and foreign prices and interest rates, but *is* rejected for oil prices indicating monetary policy can not be conducted irrespective of its understanding; strong exogeneity is rejected for all variables; and super exogeneity is not rejected for domestic and foreign prices but *is* rejected for domestic and foreign interest rates precluding valid inference on policy simulations affecting the latter. Last, the dynamic short-run specification produces reliable forecasts with the caveat that caution must be taken when exchange rate targets are reset.

The empirical investigation uses the studies of Johansen and Juselius (1992), Hunter (1992) and Watson (2003b) among others as launch points. Using an identical dataset for the UK, the first two studies both found a long-run UIP (interest rate differential) relation and a long-run PPP relation augmented by domestic and foreign interest rates, wherein the long-run PPP relation found in the latter study was augmented also by oil prices. Using data for TT Watson (2003b) found that the long-run PPP relation in itself is rejected but a long-run relation involving oil prices is *not* rejected.

[1]Small very open economies are defined as those that face a foreign exchange constraint that is unaffected by exchange rate changes or other policies. This has implications for inter alia monetary and the exchange rate policy, see Worrell (2012).

The rest of this paper is organized as follows. Section 2 briefly describes the econometric methodology used to estimate the hypothesized monetary policy rule and develop the VEqCM. Section 3 details the dataset and important events in the sample. Section 4 investigates the long-run multivariate properties of the data and interprets the hypothetical policy rule. Sections 5 and 6 respectively present and evaluate a parsimonious VEqCM and Section 7 concludes.

2 Econometric methodology

The econometric analysis commences with the modeling of the joint density of the stochastic variables. Hendry and Doornik (1994) discuss ten inter-related reasons concerning the logical and methodological basis for *Gets* modeling commencing from the joint density that include *inter alia* cointegration being a system property, being able to test weak, strong and super exogeneity and invariance, and being able to conduct multi-step ahead forecasts. The joint density of the vector of variables x_t is modeled as a vector autoregression (VAR) of the form

$$x_t = \sum_{j=1}^{s} \Pi_j x_{t-j} + \Phi q_t + v_t, \tag{2.1}$$

where $v_t \sim \mathrm{IN}[0,\Omega]$ and denotes an independent normal density with zero mean and covariance matrix Ω assumed to be (symmetric) positive definite, x_t is the vector of stochastic variables, q_t are deterministic terms including an intercept and centered seasonal dummies, Π_j is the matrix of parameter estimates on lagged x_{t-j} and Φ is the vector of parameter estimates on q_t. The system can be represented in VEqCM form, which provides a useful reformulation when x_t are I(1) and retains the same basic innovation process v_t as the VAR, and is given by

$$\Delta x_t = \pi x_{t-1} + \sum_{j=1}^{s-1} \Pi_j^* \Delta x_{t-j} + \Phi q_t + v_t. \tag{2.2}$$

Letting $\pi = \alpha\beta'$, where α is a matrix of feedback coefficients and $\beta' x_{t-1}$ are I(0) possible cointegrating relationships, the following VEqCM provides the basis for the econometric analysis

$$\Delta x_t = \alpha\beta' x_{t-1} + \sum_{j=1}^{s-1} \Pi_j^* \Delta x_{t-j} + \Phi q_t + v_t. \tag{2.3}$$

3 Data Properties

The empirical analysis uses seasonally unadjusted quarterly data spanning 1996.1-2015.4. Five observations are lost due to differencing and lags resulting in an estimation sample spanning 1997.2-2015.4. The Economic Bulletin which is jointly published by the TT Central Statistics Office and the CBTT is the data source for the TTD per USD nominal exchange rate (SS). The International Financial Statistics (IFS) published by the IMF is the data source for both TT and foreign (US) headline consumer price indexes (P) and (P^*) respectively and policy instruments, namely Treasury Bill interest rates, (RB) and (RB^*) respectively. Last, the US Energy Information Administration (EIA) is the source for West Texas Intermediate (WTI) oil prices (PO). Each series, except for interest rates which are expressed as fractions, is converted to its natural log for use in estimation, with log-levels denoted by lower-case letters. Appendix 9.2 details the full dataset.

3.1 Major events during the sample period

Major events during the sample period are listed below and discussed in detail in Appendix 9.1:

2001.1: US Fed expansionary monetary policy,
2001.3: unfortunate attacks of September 11th,
2001.4: CBTT record foreign exchange market intervention,
2002.4: CBTT record foreign exchange market intervention,
2008.1: US Fed expansionary monetary policy,
2008.2: amalgamation of Royal Bank of TT and Royal Bank of Canada,
2008.3: adverse weather conditions drive marked increases in food prices,
2008.4: onset of the global financial crisis and the collapse of commodity prices,
2008.4: US Fed enters zero lower-bound interest rate regime,
2009.1: CBTT follows Fed policy and transitions into its own low interest rate regime,
2009.1-2: TT 3-month treasury bill rate declined substantially from 2008.4-2009.2,
2010.2-3: adverse weather conditions drive marked increases in food prices,
2011.3-4: policy imposed curfew from August 21st to December 5th, 2011,
2013.3: favorable domestic, regional and global conditions drive domestic food price *deflation*,
2014.3: onset of collapse of world oil prices,
2015.4: *normalization* of US monetary policy.

4 Long-run analysis

The multivariate data analysis commences with an investigation of the stationary cointegrating relationships of the system. The empirical analysis follows the CVAR approach of Johansen (1988, 1991), Johansen and Juselius (1990) and Juselius (2006). Two variants of the system of stochastic variables (p, p^*, ss, Rb, Rb^*, po) are considered with the following discussions reserved for the latter: the first wherein the oil price, po, enters the system as an *assumed* exogenous variable and the second wherein it enters the system endogenously.[2,3] The choice of variables is influenced by Johansen and Juselius (1992), Hunter (1992) and Watson (2003b) among others. Using an identical dataset for the UK, the first two studies both found a long-run UIP (interest rate differential) relation and a long-run PPP relation augmented by domestic and foreign interest rates, wherein the long-run PPP relation found by the latter study was augmented also by the oil price.[4] Using data for TT Watson (2003b) found that the long-run PPP relation in itself does not hold and the long-run relation that does exist is augmented by the oil price.[5]

Figure 1 plots various combinations of the log-levels of p, p^*, po, ss, Rb and Rb^* over the sample 1996.1−2015.4.[6] Two key features of the data standout: first, the interest rate differential follows the PPP relation throughout the sample; second, the 2008.4 regime changes in US and TT monetary policy may have permanently affected the levels of policy rates, the spread between the policy rates and the TTD/USD exchange rate. These regime shifts motivate modifying (2.3) as follows:

$$\Delta x_t = \alpha\beta'(x', q_1)'_{t-1} + \sum_{j=1}^{s-1} \Pi_j^* \Delta x_{t-j} + \sum_{j=0}^{s-1} \Psi_j \Delta q_{1t-j} + \Phi q_{2t} + v_t, \tag{4.1}$$

where $x_t' = [p, p^*, ss, Rb, Rb^*, po]_t$, $q_{1t} = [D_{pr}]_t$, $q_{2t}' = [D_{cp}, D_{ff}, D_{at}, D_{sr}, CS, CS_{-1}, CS_{-2}]_t$, and $q_t' = [q_{1t}, q_{2t}']$. The variable in q_{1t} accounts for the new policy regimes entered by the Fed and the CBTT at the onset of the global financial crisis and is defined by D_{pr}=1 in 1996.1−2008.4 and zero otherwise. The variables in q_{2t} account for interventions related to conditions affecting TT inflation/deflation, D_{cp}; sharp changes in the Fed policy rate, D_{ff}; the unfortunate events of September 2001, D_{at}; and events related to *unanticipated* appreciations/depreciations in the TTD/USD exchange rate, D_{sr}. They are defined by D_{cp}=1 in 2010.2, 1 in 2010.3 and -1 in 2013.3; D_{ff}=1 in 2001.1 and 1 in 2008.1; D_{at}=1 in 2001.3; and D_{sr}=1 in 2001.4, -1 in 2002.2, -1 in 2008.2, -.5 in 2014.3 and .5 in 2015.4.

[2] Weak exogeneity of the oil price is tested in the second variant and is rejected. The first variant maintains this assumption, however, as the results provide insight into the long-run interactions of the system.

[3] Discussion of the system conditioned on the oil price is presented in Appendix 9.3.

[4] Hunter (1992) found that the oil price variable cannot be excluded from the system altogether, however, did not report results suggesting that it is *not* long-run weakly exogenous.

[5] Note domestic and foreign interest rates were not considered as augmenting variables in the TT PPP relation.

[6] Note plots (c) and (f), i.e. those in the right column, are adjusted to have equal means and ranges.

Cointegration analysis commences with a fifth-order VAR with an intercept, centered seasonal dummies and regime dummies, D_{cp}, D_{ff}, D_{at}, D_{sr}, D_{pr}. Including a linear trend in the specification led to parameter instability and so was left out. The fundamental change in US and TT monetary policy is hypothesized to have affected the long-run relations and so the intervention dummy, D_{pr}, is restricted to the cointegration space to test this hypothesis.[7]

4.1 CVAR with endogenous oil price

Simplification tests on an initial VAR(5) system suggested that a VAR(4) was sufficient for the present analysis, see Table 1 for reduction test statistics.[8] The lag order was selected such that the system and single equation diagnostic tests indicated that the model specification was a satisfactory approximation to the unknown data generating process (DGP). In particular, the appropriateness of the specification was tested against the single equation and system variations of the Portmanteau test, the AR 1-4 test, the Jarque-Bera test for normality, the ARCH test for homoskedasticity and Ramsey's test for regression specification (RESET). Figures 2 and 3 display the system graphical diagnostics and recursive evaluation statistics respectively.

The determination of the number of cointegration vectors is based on the results of formal testing, the interpretability of the obtained coefficients of the eigenvectors, and graphical examination of the recursive eigenvalues. Table 2 reports the formal test results of the cointegration analysis, i.e. the eigenvalues and the associated trace (λ_{trace}) and maximum (λ_{max}) eigenvalue statistics along with the estimated eigenvectors and adjustment coefficient vectors, β and α respectively.

Formal tests results suggests there is at least one cointegrating vector and at most two. Specifically, the standard trace and maximum eigenvalue test statistics suggests there are two cointegrating relations and the respective degrees of freedom corrected statistics suggests there is only one. This presents us with two potential economic scenarios to examine, one each for $r = 1, 2$, where r is the number of cointegrating relations. The notion of an economic scenario aims of bridge the gap between abstract theoretical models and the stochastic properties of the data, where the idea of an economic scenario is to specify explicitly all implications of a particular choice of integration and cointegration indexes such that they can be checked against the data, see Juselius (1998). Economic theory suggests there are potentially two cointegrating vectors among the variables in the system, the PPP relation and the interest rate differential (UIP) relation.

[7] This regime has been characterized by zero lower bound policy rates for the Fed; and by markedly lower interest rate spreads essentially mirroring the Fed, albeit with a lag and an *allowed* depreciation of the exchange rate for the CBTT. At the end of the current sample these fundamental policy regime shifts were still in effect and appear to have permanently affected the steady-state level of interest rates, the interest rate spread and the exchange rate.

[8] Simplification tests an initial VAR(6) also suggested a VAR(4) was sufficient for the analysis.

The first eigenvector clearly contains the interest rate differential relation between the domestic and foreign interest rates Rb and Rb^* respectively. This relation however seems to be augmented by a long-run exchange rate relation and perhaps also the oil price and the regime shift in monetary policy.[9] The second eigenvector partly resembles the interest rate differential relation regarding the coefficient signs, however, the discrepancy in the coefficient estimates suggests this relation may not hold. Altogether, interpretation of the eigenvectors suggests there is at least one long-run relation and perhaps a second relation that is also present in the first.

Figures 4 and 5 plot the recursive eigenvalues and the unrestricted cointegrating relations for the first four estimated long-run relations. Visual inspection of the recursive eigenvalues supports the formal result that there is at least one cointegrating relation as the first eigenvalue is non-zero throughout the sample and is fairly constant from mid-sample onward. The second eigenvalue is also fairly constant from mid-sample, however, it is nearer zero. Visual inspection of the unrestricted cointegrating relations strongly suggests there is only one stationary long-run relation. Altogether, the results suggest the economic scenario of $r = 1$ is preferable from a statistical point of view.

4.2 An economic scenario for $r = 1$

Before moving on to structural hypothesis tests on the cointegrating vectors I first investigate the time series properties of the individual stochastic variables. Specifically, the series are tested for stationarity, H_{sta}, weak exogeneity, H_{we}, and individual significance in the cointegrating relation, H_{sig}.[10] The test results are presented in the top panel of Table 3. The multivariate stationarity test results indicate that none of the variables are stationary. The variable significance tests strongly suggests that all variables are individually significant to the long-run relation, save for the regime dummy albeit barely with a test statistic of 1.85 and a p-value of 0.174, distributed as a $\chi^2(1)$.

The weak exogeneity test results suggest long-run weak exogeneity is *not* rejected for domestic and foreign prices; is safely rejected for the exchange rate; is not rejected for the domestic and foreign interest rates with *p-values* 0.085 and 0.131 respectively; and *is* safely rejected for the oil price. Joint hypotheses of weak exogeneity were tested for domestic and foreign prices and the foreign interest rate, and for these series in addition to the domestic interest rate. Weak exogeneity was not rejected for the former with a test statistic of 3.45 and p-value of 0.328, distributed as a $\chi^2(3)$; and also for the latter with a test statistic of 5.71 and a p-value of 0.222, distributed as a

[9] Note the coefficient signs for domestic and foreign prices and the exchange rate match that of the PPP hypothesis but the magnitudes suggest otherwise.

[10] H_{sta} and H_{sig} are tests on the coefficients of β' and H_{we} are tests on the coefficients of α. For example, testing the stationarity, individual significance and weak exogeneity of domestic prices involves testing $\beta' = (1, 0, 0, 0, 0, 0)$, $\beta' = (0, *, *, *, *, *)$ and $\alpha = (0, *, *, *, *, *)$ respectively, where $*$'s represent unrestricted values.

$\chi^2(4)$. These results suggest that inference on the system can be obtained from a model conditional on domestic prices and foreign interest rates, and perhaps also on domestic interest rates, without loss of information.

Appendix 9.3 presents the long-run analysis results for the CVAR conditioned on the oil price. The weak exogeneity results are similar save for long-run weak exogeneity of foreign prices being safely rejected with a test statistic of 15.44 and p-value of 0.00. This result motivated including the oil price as an endogenous variable and may be indicative of the long-run dynamics of the system. For example, it may suggest Granger-causality from foreign to domestic prices leading to imported inflation thus suggesting that inference conditional on foreign prices is not valid, see Primus *et. al* (2011) and Mahabir and Jagessar (2011); or that foreign prices are simply in part reflecting changes in oil prices which would suggest that the assumption of weak exogeneity of oil prices is invalid.[11] The latter suggestion was investigated empirically by comparing the weak exogeneity results of both CVAR systems.[12] Recall weak exogeneity of foreign prices is not rejected but is rejected for oil prices in the endogenous CVAR. This result provides empirical evidence that oil price shocks are transmitted though the TT economy in part via its effects on foreign prices.

4.3 Testing structural hypotheses

To empirically assess the economic theories hypothesized among the variables of the system the cointegration implications are tested. The results are displayed in the mid panel of Table 3. Johansen and Juselius (1992) provide the framework for testing these structural hypotheses in the cointegration space. Hypotheses H_{1r} and H_{1u} are related to the long-run PPP relation and test whether this relation holds with the other coefficients restricted to equal zero and unrestricted to be determined by the model respectively. Both the restricted and unrestricted PPP relations are safely rejected with test statistics 75.55 distributed as $\chi^2(6)$ with p-value of 0.00, and 42.31 distributed as $\chi^2(2)$ with p-value of 0.00 respectively. These results suggest there is little empirical support for the PPP relation and consequently rule out one of two dominant theories of price formation in open economies, the other dominant theory being money demand.

Hypotheses H_{2r} and H_{2u} are related to the long-run interest rate differential relation and similarly tests whether this relation holds with the other coefficients restricted to zero and unrestricted to be determined by the model respectively. The restricted relation is rejected with a test statistic

[11]See Bernanke *et al.* (2004) and Hamilton and Herrera (2004) *inter alia* for studies investigating the effects of oil price shocks, the US macroeconomy and US monetary policy.

[12]Specifically, rejection of weak exogeneity of oil prices but not foreign prices in the endogenous CVAR in conjunction with rejection of weak exogeneity of foreign prices in the conditional CVAR is evidence that oil price shocks are transmitted through the TT economy in part via its effects on foreign prices.

of 67.51 $\chi^2(6)$ with a p-value of 0.00, however, the unrestricted relation is convincingly not rejected with a test statistic of 0.492 distributed as $\chi^2(1)$ with a p-value of 0.48. The results provide empirical support for the interest rate differential relation, however, the relation needs to be augmented by price and exchange rate variables to be explained and is perhaps suggestive of Fisher open parity.[13]

The result that the interest rate differential relation requires augmentation by the other variables suggests that the CBTT may be following a policy rule for what is perhaps its most important target variable in the nominal exchange rate, ss. Review of the Monetary Policy Report published by the CBTT dating as early as 2005 – as early as is published electronically – states *"The CBTT conducts monetary policy geared towards the promotion of low inflation and a stable foreign exchange market that is conducive towards sustained growth in output and employment."* This statement suggests that the central bank may seek to adjust the level of domestic interest rates relative to foreign interest rates if the exchange and inflation rates deviate from their targets, s_t^t, and Δp_t^t respectively.[14] The policy rule may also take into account deviations in foreign inflation from its target, Δp_t^{*t}, as foreign prices have been found to Granger-cause domestic prices; and oil prices beyond say a budgeted price, po_t^t, as the fiscal budget is based on *budget* oil and natural gas prices. The following relation between the interest rate spread and deviations of the exchange and inflation rates and oil prices from their targets is hypothesized to be the central bank reaction rule:

$$Rb_t = Rb_t^* + a_1(ss_t - ss_t^t) + \Delta a_2(p_t - p_t^t) + \Delta a_3(p_t^* - p_t^{*t}) + a_4(po_t - po_t^t) + Rb_0 + u_t, \qquad (4.2)$$

where Rb_0 is a constant, $a_1 \leq 0$, $a_2 \geq 0$, $a_3 \leq 0$, $a_4 \leq 0$ and the residual $u_t \sim \mathrm{I}(0)$. The coefficient on a_4 may be depend *inter alia* on how deviations in oil prices from its budgeted value affect the central government's fiscal budget and so may differ from the a priori expected sign.[15]

There is little empirical evidence suggesting any of the variables are I(2) for the given sample. This precludes polynomially cointegrating relations among the variables and implies that only directly cointegrating relations are possible. Taking this into consideration, the policy rule in this case is restructured to include the levels of the domestic and foreign price series in place of their first differences and is as follows:[16]

$$Rb_t = Rb_t^* + a_1(ss_t - ss_t^t) + a_2(p_t - p_t^t) + a_3(p_t^* - p_t^{*t}) + a_4(po_t - po_t^t) + Rb_0 + u_t. \qquad (4.3)$$

[13]Fisher open parity implies the stationarity of domestic-foreign interest and inflation rate differentials and domestic and foreign real interest rates.The current information set allows testing of these implications.

[14]Note that nations aiming to maintain the rate of exchange rate depreciation will want to use Δss_t^t in place of s_t^t.

[15]These sign restrictions are noted in the literature, see Alstad (2010).

[16]Note the interpretation of the directly and polynomially cointegrating policy rules may differ slightly but the expected signs on the variables are unchanged. Specifically, the directly cointegrating relation more closely resembles reaction to deviations between domestic and foreign price level differentials, where the weights on foreign and domestic prices are not required to be equal. Browne (2016) found asymmetric short run effects between foreign and domestic prices in his investigation of imports of nondurable consumers' goods, which suggests augmenting the interest rate differential relation to incorporate short-run effects, see Johansen and Juselius (1992).

Empirical support for the hypothesized policy rule stated in (4.3) was investigated following the methodology of Johansen and Juselius (1992). The results are reported in the bottom panel of Table 3. Hypothesis H_{3s} tests whether the coefficient on the exchange rate equals unity allowing the other variables to be determined by the model and hypothesis H_{3sr} restricts the coefficient on the regime dummy to equal zero. Neither hypothesis is rejected, however, hypothesis H_{3s} has more empirical support with the larger reported p-value of 0.756 compared to a p-value of 0.456 for hypothesis H_{3sr}. The large reduction in the p-value when a zero restriction is imposed on the coefficient of the regime dummy suggests that despite being *barely* insignificant the regime dummy may contribute useful information to the long-run relation and so is retained. Altogether, these results provide empirical support for the hypothesized central bank policy rule.[17]

4.4 Interpreting the policy rule

Imposing the restrictions of hypothesis H_{3s} results in the following cointegrating relation:

$$ecm_{f,t} = -0.071p_t + 0.258p_t^* + ss_t + (Rb_t - Rb_t^*) - 0.015po_t + 0.009D_{pr,t}. \tag{4.4}$$

The hypothesized and empirically supported policy rule provides insight into how the central bank determines its policy interest rate when formulating monetary policy. Before interpreting the policy rule, however, the error-correction term is defined by an identity as this representation is more readily interpretable. The resulting transformation provides the *redefined* policy rule as:

$$ecm_{f,t} \equiv ecm_{f,t-1} - 0.071\Delta p_t + 0.258\Delta p_t^* + \Delta ss_t + \Delta(Rb_t - Rb_t^*) - 0.015\Delta po_t + 0.009\Delta D_{pr,t}. \tag{4.5}$$

The policy rule suggests that the CBTT can be expected to raise its policy rate relative to the foreign policy rate in response to an appreciation of the exchange rate below its target, or alternatively a depreciation above the target; an increase in foreign prices below the target set by Fed, i.e. realized inflation below the target rate or perhaps deflation; an increase in domestic prices above the target, i.e. realized inflation above the target rate; and an increase in oil prices, perhaps relative to the long-run price or budgeted price for the current period. Additionally, the CBTT can be expected to increase the spread on its policy rate relative to the foreign policy rate during crisis regimes.

The long-run coefficient estimates of the policy rule have the a priori expected signs save for the coefficient on the oil price. Raising the policy rate when domestic inflation is above its target is consistent with monetary policy tightening when there is upward pressure on prices or when the economy is overheating. Lowering the policy rate when foreign inflation is above its target

[17] Table 4 presents the weak exogeneity test results with tested jointly with hypothesis H_{3s}

follows from maintaining a real interest rate spread, wherein the much larger coefficient is perhaps attributable to the Fed's US policy rate response to US inflation having an additional policy response by the CBTT. Increasing the policy rate when oil prices rise seems counter intuitive as this may lead to further exchange rate appreciation beyond that caused by the increase in oil prices. One possible explanation for this result is that the oil price increase leads to increased government and private spending requiring the central bank increase the policy rate to mitigate potential overheating and crowding out. Increasing the policy rate during crisis regimes is also plausible as the need to attract or curtail the outflow of FDI is greater during economic crises and interest rate differentials are viewed as necessary for attracting essential FDI.[18] Raising the policy rate when the exchange rate appreciates below its target is in line with both UIP and Fisher open parity.

5 Short-run analysis

The short-run analysis is based on the 3-equation conditional model in (Δss, Δpo, $ecm_{f,t}$) where the error correction term is defined by the identity given in (4.5).[19] The available information set for the conditional system includes (Δp_{t-i}, Δp^*_{t-i}, Δss_{t-i}, ΔRb_{t-i}, ΔRb^*_{t-i}, Δpo_{t-i}) for $i = 0, ..., 4$, an intercept, centered seasonal dummies and regime dummies D_{cp}, D_{ff}, D_{at} and D_{sr}. Note this information set was by no means designed to model oil prices, which in itself is a much studied empirical issue and beyond the scope of this paper.[20] In light of this an autoregressive time-series model of the oil price is formulated to complete the conditional subsystem − a random walk model augmented with impulse dummies in particular. The results presented and discussions that follow focus solely on the results of the exchange rate equation.

Equation (5.1) presents the FIML estimates of the final model and Figure 6 presents the graphical diagnostic statistics.[21] Results indicate there are no significant contemporaneous effects on the exchange rate save for oil prices and lagged changes of the stochastic variables were generally significant, however, except for the exchange rate.[22] In particular, the exchange rate depreciated

[18]See Worrell (2012) for discussions of the importance of earning foreign exchange in small very open economies.

[19]Given the long-run weak exogeneity of p, p^*, Rb and Rb^* for the parameters of the exchange rate equation a conditional model in ss and po is sufficient for valid inference, i.e. there is no loss of information.

[20]It is unlikely that TT economic conditions affect world oil prices and so any estimation results for the oil price equation using the current information set may be safely considered spurious.

[21]Rejection of the LR test of over identifying restrictions is in large part due to the restrictions placed on the oil price equation. Restricting the system to the exchange rate equation and the identity results in the following statistics:

log-likelihood = 387.83 -T/2log|Omega| = 494.25
no. of observations = 75 no. of parameters = 13
LR test of over-identifying restrictions: $\chi^2(30) = 40.113$ [0.103]

[22]Oil prices were allowed to enter the equation for *dss* contemporaneously as residual cross-correlations between *dss* and *dpo* in the general unrestricted model (GUM) were quite large at 0.4.

with lagged changes in domestic and foreign prices albeit at different lags, lagged changes in domestic interest rates, *more* recent changes in foreign interest rates, and the term, d^4po_t, which may be interpreted as a data-based predictor of future oil price increases; and appreciated with the term, $d_2Rb^*_{t-3}$, which may be interpreted as statistically smoothed *less* recent foreign interest rate changes. Note that changes in foreign prices affect the exchange rate at a shorter lag than domestic prices and is perhaps suggestive that foreign prices Granger-cause domestic prices, an increasingly common empirical result.

$$
\begin{aligned}
\text{dss} = \; & \underset{(0.014)}{0.065}\ \text{dp}_{t-3} + \underset{(0.035)}{0.1}\ \text{dp*}_{t-2} + \underset{(0.16)}{0.67}\ \text{dRb}_{t-2} \\
& + \underset{(0.23)}{0.65}\ \text{dRb*}_{t-1} - \underset{(0.038)}{0.27}\ \text{ecm}_{f\,t-1} - \underset{(0.0017)}{0.013}\ \text{Dat}_t \\
& + \underset{(0.0009)}{0.017}\ \text{Dsr}_t - \underset{(0.28)}{2}\ \text{d}_2\text{Rb*/2}_{t-3} + \underset{(0.00076)}{0.0034}\ \text{d}^4\text{po}_t \\
& + \underset{(0.1)}{0.73} + \underset{(0.00056)}{0.00024}\ \text{CS}_t - \underset{(0.00064)}{0.001}\ \text{CS}_{t-1} - \underset{(0.00053)}{0.0001}\ \text{CS}_{t-2}
\end{aligned}
\tag{5.1}
$$

log-likelihood = 430.08 -T/2log|Omega| = 642.93
no. of observations = 75 no. of parameters = 19
LR test of over-identifying restrictions: $\chi^2(65)$ = inf** [0.000]

The estimate of the short-run adjustment coefficient is very significant and suggests that approximately 25 percent of long-run disequilibrium is adjusted each quarter. This estimate may appear low when considering that the CBTT *seems* to intervene in the foreign exchange market, at record levels if needed, in the quarters immediately following unanticipated shocks to the exchange rate. Nevertheless, as will be discussed in the following section, the adjustment coefficient estimate is both significant and highly constant throughout the sample which lends credence to this estimate.

The regime dummies D_{at} and D_{sr} were both highly significant but not regime dummies D_{cp} and D_{ff}. First, this suggests that unanticipated external events which affected financial markets had significant effects on the exchange rate which required above normal, record if needed, CBTT intervention in the foreign exchange market. Second, it indicates that unanticipated events influencing large changes in foreign interest rates which do not lead to large effects on financial markets and unforeseen events affecting domestic prices do not influence the exchange rate in the short-run.

The absence of lagged values of the exchange rate suggests there is little empirical evidence of random walk behavior in the exchange rate equation. This result may seem surprising given the fact that random walk models are quite famous exchange rate models. It, however, lends large support to the long-run policy rule and domestic and external forces being the main determinants of the exchange rate, a result that is becoming increasingly known for small *very* open economies.

6 Model evaluation

The conditional model presented in (5.1) is evaluated on several criteria.[23] Section 6.1 tests the constancy of the model's estimates. Section 6.2 investigates the strong and super exogeneity of the marginal processes for the parameters of (5.1) and gives implications for these results regarding the Lucas critique, see Lucas (1976). Section 6.3 examines the model's forecast accuracy and Section 6.4 interprets the complete empirical model in light of the findings of the evaluation process.

6.1 Constancy

Figures 7 and 8 present the recursive estimates, the 1-step residuals, ± 2 standard error bands and the 1-step ahead Chow statistics, see Chow (1960). The recursive coefficient estimates display little variation throughout the sample, save for a minor change in the level of a few variables in 2011.1. The 1-step Chow statistics are all insignificant at the 1 percent level save for the 2011.1 observation which is significant with a test statistic of 9.16 distributed as an $F(1,40)$ with a p-value of 0.004, and are only significant at the 5 percent level for three observations (2002.2, 2014.2, 2015.1). The breakpoint Chow statistics, however, are nowhere significant at the 1 percent level and are only barely significant at the 5 percent level in a few instances (2010.1, 2010.2, 2011.1). These statistics suggest that including an impulse dummy to account for what appears to be a reassigning of the *target* level of the exchange rate in 2011.1 may be appropriate.

The significance of the 2011.1 impulse dummy was tested in (5.1). The impulse dummy was found to be insignificant with a t-statistic of -1.67 and a p-value of 0.101. Including the impulse dummy does, however, make all 1-step Chow statistics insignificant at the 1 percent level and leaves only two observations barely significant at the 5 percent level (2011.2, 2015.1); and makes all breakpoint Chow statistics insignificant at the 5 percent level. Altogether, the recursive statistics found prior to including the 2011.1 impulse dummy and the test results regarding its significance point to the empirical constancy of the model's parameters and stability of the model structure.

[23] It is important to note that the model is evaluated without the non-zero parameter restrictions imposed. This model is presented in Appendix 9.4. Imposing these restrictions, however, yields similar results.

6.2 Exogeneity

Ericsson (1992) gives a rich overview of the notions of cointegration, exogeneity and policy analysis. Specifically, strong exogeneity is defined as the conjunction of weak exogeneity and Granger noncausality and super exogeneity the conjunction of weak exogeneity and invariance.[24] It is easily seen that strong exogeneity of the marginal processes is rejected in all cases. In particular, Granger noncausality of the marginal processes is rejected since estimation results in (5.1) indicate statistically significant feedback from lagged values of all stochastic variables.

Two empirical tests of super exogeneity are considered (*i*) the constancy test and (*ii*) the invariance test, see Ericsson and Irons (1995) for further discussion and empirical examples. The first test involves establishing the constancy of the conditional model and examining the (non)constancy of the marginal process. Super exogeneity of the marginal process for the parameters of interest then follow from the constancy of conditional model and the non constancy of the marginal models. The second test requires empirically *more* constant and better fitting marginal models to be developed and involves testing the invariance of the parameters of these improved marginal models in the conditional model.

6.2.1 The constancy test for super exogeneity

Marginal models for p, p^*, Rb and Rb^* are developed starting with fifth-order autoregressive models. Equations (6.1)$-$(6.4) present the final marginal models. The standard F statistic for testing the validity of the reduction from the general fifth-order models and summary statistics are presented below each equation.[25] The F statistics suggest that the reductions to the final marginal models are statistically acceptable.

Figures 9 and 10 present 1-step residuals with ± 2 standard error bands and the break-point Chow statistics. The marginal models of p and p^* are clearly not constant but those of Rb and Rb^* do appear constant. This suggests that super exogeneity of domestic and foreign prices in (5.1) is not rejected, which follows from the constancy of the conditional model and the nonconstancy of the marginal models; but super exogeneity of domestic and foreign interest rates is rejected, which follows from constancy of both marginal models.

[24] Strong exogeneity ensures valid conditional forecasting and super exogeneity ensures valid policy simulations.

[25] Reductions from sixth-order autoregressive models led to the same marginal processes presented.

$$
\begin{aligned}
\text{dp} \;=\; & \underset{(0.12)}{0.25}\ \text{dp}_{t-1} + \underset{(0.0023)}{0.011} \\
& - \underset{(0.0044)}{0.0021}\ \text{CS}_t + \underset{(0.0043)}{0.00095}\ \text{CS}_{t-1} + \underset{(0.0043)}{0.0021}\ \text{CS}_{t-2}
\end{aligned}
\tag{6.1}
$$

$\hat{\sigma} = 0.0133,\ R^2 = 0.0723,\ T = 75,\ F(3,67) = 1.0016$ p-value$= 0.3977$.

$$
\begin{aligned}
\text{dp}^* \;=\; & \underset{(0.12)}{0.31}\ \text{dp}^*{}_{t-1} - \underset{(0.12)}{0.26}\ \text{dp}^*{}_{t-2} + \underset{(0.001)}{0.0051} \\
& + \underset{(0.002)}{0.0065}\ \text{CS}_t + \underset{(0.0022)}{0.0084}\ \text{CS}_{t-1} + \underset{(0.002)}{0.0021}\ \text{CS}_{t-2}
\end{aligned}
\tag{6.2}
$$

$\hat{\sigma} = 0.00543,\ R^2 = 0.440,\ T = 75,\ F(2,67) = 0.809$ p-value$= 0.450$.

$$
\begin{aligned}
\text{dRb} \;=\; & \underset{(0.097)}{0.56}\ \text{dRb}_{t-1} - \underset{(0.00015)}{0.0001} - \underset{(0.00041)}{0.00038}\ \text{CS}_t \\
& - \underset{(0.00041)}{4.4e-05}\ \text{CS}_{t-1} - \underset{(0.00041)}{0.0002}\ \text{CS}_{t-2}
\end{aligned}
\tag{6.3}
$$

$\hat{\sigma} = 0.00125,\ R^2 = 0.329,\ T = 75,\ F(3,67) = 1.699$ p-value$= 0.176$.

$$
\begin{aligned}
\text{dRb}^* \;=\; & \underset{(0.1)}{0.6}\ \text{dRb}^*{}_{t-1} + \underset{(0.12)}{0.35}\ \text{dRb}^*{}_{t-3} - \underset{(0.11)}{0.35}\ \text{dRb}^*{}_{t-4} \\
& - \underset{(8.9e-05)}{6.3e-05} + \underset{(0.00025)}{0.0006}\ \text{CS}_t + \underset{(0.00025)}{0.0004}\ \text{CS}_{t-1} + \underset{(0.00026)}{0.00086}\ \text{CS}_{t-2}
\end{aligned}
\tag{6.4}
$$

$\hat{\sigma} = 0.000751,\ R^2 = 0.488,\ T = 75,\ F(1,67) = 0.144$ p-value$= 0.705$.

6.2.2 The invariance test for super exogeneity

The marginal models of p p^*, Rb and Rb^* were extended to including impulse and step dummies as proxies for changes in the marginal processes. Equations (6.5)−(6.8) present the improved marginal models with summary statistics displayed below each equation.[26]

[26] The improved marginal processes were determined by applying the *Autometrics* algorithm to the marginal models with the constant and seasonal dummies set unrestricted. Impulse and step indicator saturation (IIS and SIS) were

$$
\begin{aligned}
\mathrm{dp} \;=\; & -\underset{(0.0098)}{0.037}\ \mathrm{I}_{13.3,t} - \underset{(0.0073)}{0.032}\ \mathrm{S}_{08.2,t} + \underset{(0.0084)}{0.038}\ \mathrm{S}_{08.4,t} \\
& - \underset{(0.0086)}{0.05}\ \mathrm{S}_{10.1,t} + \underset{(0.0092)}{0.062}\ \mathrm{S}_{10.3,t} - \underset{(0.0059)}{0.021}\ \mathrm{S}_{11.2,t} - \underset{(0.094)}{0.07}\ \mathrm{dp}_{t-1} \\
& + \underset{(0.0026)}{0.018} - \underset{(0.0031)}{0.00029}\ \mathrm{CS}_t - \underset{(0.0031)}{0.00089}\ \mathrm{CS}_{t-1} + \underset{(0.0031)}{0.00023}\ \mathrm{CS}_{t-2}
\end{aligned}
\tag{6.5}
$$

$\hat{\sigma} = 0.00931,\ R^2 = 0.584,\ T = 75.$

$$
\begin{aligned}
\mathrm{dp}^* \;=\; & \underset{(0.088)}{0.38}\ \mathrm{dp}^*{}_{t-1} - \underset{(0.089)}{0.14}\ \mathrm{dp}^*{}_{t-2} - \underset{(0.0043)}{0.032}\ \mathrm{I}_{08.4,t} \\
& + \underset{(0.00076)}{0.0044} + \underset{(0.0015)}{0.006}\ \mathrm{CS}_t + \underset{(0.0017)}{0.008}\ \mathrm{CS}_{t-1} + \underset{(0.0016)}{0.00067}\ \mathrm{CS}_{t-2}
\end{aligned}
\tag{6.6}
$$

$\hat{\sigma} = 0.00409,\ R^2 = 0.686,\ T = 75.$

$$
\begin{aligned}
\mathrm{dRb} \;=\; & \underset{(0.075)}{0.38}\ \mathrm{dRb}_{t-1} + \underset{(0.00098)}{0.0046}\ \mathrm{S}_{01.2,t} - \underset{(0.00096)}{0.0046}\ \mathrm{S}_{01.3,t} \\
& + \underset{(0.00072)}{0.0045}\ \mathrm{S}_{08.4,t} - \underset{(0.00071)}{0.0045}\ \mathrm{S}_{09.2,t} + \underset{(0.00018)}{3e-06} \\
& - \underset{(0.00031)}{0.0001}\ \mathrm{CS}_t + \underset{(0.0003)}{0.00015}\ \mathrm{CS}_{t-1} + \underset{(0.0003)}{4.6e-05}\ \mathrm{CS}_{t-2}
\end{aligned}
\tag{6.7}
$$

$\hat{\sigma} = 0.000922,\ R^2 = 0.656,\ T = 75.$

$$
\begin{aligned}
\mathrm{dRb}^* \;=\; & \underset{(0.042)}{0.22}\ \mathrm{dRb}^*{}_{t-1} - \underset{(0.00028)}{0.0016}\ \mathrm{I}_{98.4,t} - \underset{(0.00031)}{0.0017}\ \mathrm{I}_{07.4,t} - \underset{(0.00031)}{0.0027}\ \mathrm{I}_{08.1,t} \\
& - \underset{(0.00028)}{0.0032}\ \mathrm{I}_{08.4,t} + \underset{(0.00021)}{0.0029}\ \mathrm{S}_{00.4,t} - \underset{(0.00034)}{0.0023}\ \mathrm{S}_{01.2,t} + \underset{(0.00039)}{0.0027}\ \mathrm{S}_{01.3,t} \\
& - \underset{(0.00029)}{0.0029}\ \mathrm{S}_{01.4,t} - \underset{(0.00014)}{0.00096}\ \mathrm{S}_{04.1,t} + \underset{(0.00016)}{0.0011}\ \mathrm{S}_{06.3,t} - \underset{(0.00014)}{0.00035}\ \mathrm{S}_{08.1,t} \\
& + \underset{(5e-05)}{7.4e-06} + \underset{(9.6e-05)}{0.00014}\ \mathrm{CS}_t - \underset{(9.3e-05)}{0.00012}\ \mathrm{CS}_{t-1} - \underset{(9.3e-05)}{3.1e-05}\ \mathrm{CS}_{t-2}
\end{aligned}
\tag{6.8}
$$

applied jointly with the target size set at 0.001 for all models except ΔRb^* where it was set to 0.0001. The smaller target size for ΔRb^* still managed to pick up what may be considered *too* many impulses given the sample size but was used nonetheless.

$\hat{\sigma} = 0.000265$, $R^2 = 0.945$, $T = 75$.

The invariance test results point to the invariance of the parameters in (5.1) to changes in the price processes, Δp and Δp^*, but not the interest rate processes, ΔRb and ΔRb^*. Specifically, the right-hand side (RHS) variables of the Δp marginal model were individually and jointly insignificant in (5.1) with an F statistic of F(7,53)= 1.253 and p-value of 0.291. The variables of the Δp^* marginal process were also individually and jointly insignificant with an F statistic of F(2,58)= 0.274 and p-value of 0.762. Joint testing of the invariance of the variables of Δp and Δp^* reported an F statistic of F(9,51)= 0.973 and p-value of 0.473.

Invariance of the RHS variables of the ΔRb marginal process was rejected when tested jointly with an F statistic of F(4,57)= 15.100 and p-value of 0.000, and also rejected when tested individually for some variables. It is interesting to note that this result can be deduced since D_{at}, which was found to be highly significant in (5.1), is simply the combination of step dummies $S_{01.2}$ and $S_{01.3}$ in the improved marginal process for ΔRb.[27] The RHS variables of the ΔRb^* marginal process are mostly individually insignificant, save for D_{at} and $S_{08.1}$, but are nonetheless jointly significant. The latter dummy variable is significant at the 5 percent level and may be viewed as the regime dummy for the Fed entering its recessionary monetary policy stance before fully understanding the scope of the recession and ultimately reverting to its zero lower-bound policy regime. This step dummy, however, becomes insignificant with the removal of the other insignificant dummies.

The results of (*i*) and (*ii*) strongly suggest that the parameters (5.1) are invariant to changes in domestic and foreign price processes but not to changes in the interest rate processes. These results are critical from a policymaking perspective as they indicate that valid inference on policy simulations may be made from policies altering the paths of price levels but not from those altering the paths of interest rates, which in this case are the primary instruments of monetary policy.[28] More generally, this result potentially has massive implications for a central bank that places immense emphasis on exchange rate stability.

[27] D_{at} was excluded from the invariance test as it is perfectly captured by the combination of $S_{01.2}$ and $S_{01.3}$. $S_{08.4}$, i.e. D_{pr} was also excluded since it was restricted to the cointegration space. t tests for its inclusion in the short-run space were insignificant with a test statistic of -1.15 and p-value of 0.254.

[28] These results also suggest an important role for model-based expectations of interest rate variables. It is important to note, however, that mis-specification of a conditional model typically generates parameters in the conditional model that are not invariant to changes in the marginal processes. Thus, potential mis-specification, perhaps through omitted variables, may be responsible for non-invariant parameters and the rejection of super exogeneity.

6.3 Forecasting

1-step ahead ex ante and ex post forecasting from (5.1) is straightforward but may require forecasts of oil prices. Multistep-ahead forecasting is also possible but will require the full dynamic system to be specified. In light of the conditional subsystem specification only 1-step ahead ex post forecasts are generated and discussed.

For the ex post forecasting exercise (5.1) is re-estimated over the subsample 1997.2−2013.4 and the re-estimated parameters are then used to produce forecasts over the period 2014.1−2015.4.[29] Figure 11 displays the actual, fitted and forecast values of changes in the exchange rate with $\pm$ 2 standard error bars for each forecast. Forecasts presented in the top row have standard errors that are the error variances only while those in the bottom row include parameter uncertainty.[30] The forecasts track the realized values of the exchange rate fairly well with the majority point forecasts falling within the standard error bars and near the realized values. Most point forecasts also successfully predict the directional changes which is surprising given the high uncertainty surrounding oil prices during the forecast period. These results suggest (5.1) may be well suited for forecasting the exchange rate with the caveat that caution must be taken when the CBTT appears to have reset its exchange rate target.

6.4 Economic interpretation

The empirical evidence supports a stable monetary policy rule involving the interest rate differential, the exchange rate, domestic, foreign and oil prices and a regime dummy for the zero lower-bound monetary policy regime. The homogeneous interest rate differential elasticities provide empirical support for US monetary policy being a key, and perhaps the most influential, factor affecting TT monetary policy decisions. The relative elasticities of the exchange rate and domestic and foreign prices is indicative of the much larger emphasis the CBTT places on exchange rate stabilization relative to promoting low and stable domestic inflation. The greater emphasis on foreign prices is perhaps suggestive of its *inflationary* effects on domestic prices. The significance of oil prices and the regime dummy suggest that TT's ability to earn foreign exchange and global economic crises are also taken into consideration when setting monetary policy.

Weak exogeneity of domestic and foreign prices and interest rates is further suggestive that monetary policy is primarily concerned with exchange rate stabilization. The rejection of weak

[29] Note, no location shifts are used in the forecasting exercise.

[30] Including parameter uncertainty results in one additional point forecast falling within the standard error bands, namely the point forecast of 2015.3.

exogeneity of oil prices is further indicative of TT's strong economic reliance on energy resources, and specifically that monetary policy is not conducted exclusive of an understanding of this variable.

These findings are all in accordance with communications by the CBTT regarding its conduct of monetary policy. Though the estimated policy rule is empirically accepted it may differ from the exact rule employed by the CBTT, assuming a policy rule is employed. For example, it is plausible that the CBTT considers variables that may include or exclude those considered in this empirical investigation. Additionally, the CBTT may also change the weights it places on the parameters of its policy rule as economic conditions and/or compositions change. For these reasons, the empirically estimated policy rule presents only a first foray into estimating monetary policy rules in small *very* open economies.

7 Concluding Remarks

This study provides a first foray into empirically estimating monetary policy rules in small *very* open economies. The case of Trinidad and Tobago was investigated and an empirically accepted long-run monetary policy rule was found among the domestic and foreign interest rate differential, the exchange rate, domestic, foreign and oil prices and a regime dummy for the zero lower-bound monetary policy regime. The empirical investigation may be extended in several ways. For example, increasing the initial information set may allow more variables under consideration by the CBTT when setting monetary policy to enter the policy rule, and using a more comprehensive measure of TT's ability to earn foreign exchange, say an energy price index, may yield more precise estimates.

Short-run analysis of the exchange rate equation revealed significant contemporaneous effects from oil prices, significant lagged effects from all stochastic variables except the exchange rate and moderate adjustment to the long-run monetary policy rule. Parameter estimates of the parsimonious VEqCM are empirically constant. Strong exogeneity is rejected for all stochastic variables and super exogeneity is rejected for foreign and domestic interest rates but not prices. The latter results suggest the model is not suitable for policy selection where either interest rate is involved, however, valid inference on policy simulations may be made regarding either price level.

The approach taken in this study is not unique to TT and is in general potentially applicable to small *very* open economies. The key issues when taking this approach in other empirical investigations will be determining the measures for earning foreign exchange, this may be a commodity price for SNRNREs and renewable commodity exporters or foreign GDP for a region if tourism is the main earner; the advanced economy the central bank monitors when making its monetary policy decisions, i.e. regarding policy rate decisions, inflation, growth, unemployment etc.; and the domestic central bank's responses to shocks to variables considered in the policy rule, for example *record* foreign exchange interventions or exchange rate re/devaluations.

Future research in estimating monetary policy rules for small very open economies may potentially focus on investigating the timing and sources of changes in estimated monetary policy rules. One possibly suitable approach for this investigation is that of Impulse Indicator Saturation, see Ericsson (2012) and Ericsson and Chekmasova (2012) among others. The approach taken in this study may also potentially be extended to allow for estimating fiscal policy rules in these economies, which in many cases may be the more interesting and timely investigation.

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9 Appendix

9.1 Political interventions, regime shifts, crises and major events

This appendix discusses in greater detail the major events during the sample period.

2001.1: US Fed expansionary monetary policy

2001.3: Unfortunate attacks of September 11th.

2001.4: During the first nine months of 2001, conditions were such that the CBTT was a net purchaser of foreign exchange from the market and the exchange rate strengthened in this period. However, in 2001(4) the CBTT provided large sums of liquidity to the foreign exchange market.

2002.4: An unprecedented level of intervention in the foreign exchange market in 2002(4) was due in part to outward foreign direct investment and regional bond issues.

2008.1: US Fed expansionary monetary policy.

2008.2: The appreciation of the TTD vis-à-vis the USD was in part the result of relatively easy liquidity conditions in the domestic foreign exchange market which stemmed from increased conversions by energy companies to meet quarterly tax payments and the amalgamation of RBTT and RBC.

2008.3: The Economic Bulletin reported that higher prices for bread and cereals (4.1 percent year-on year inflation), which have a large import component; meat (5.0 percent) and vegetables (13.7 percent) contributed to the increase in food and non-alcoholic beverages inflation.

2008.4: Onset of the global financial crisis and the collapse of commodity prices.

2008.4: US Fed enters zero lower-bound interest rate regime.

2009.1: CBTT follows Fed policy and transitions into its own low interest rate regime.

2009.1-2: The Economic Bulletin mentions that the 3-month Treasury Bill rate declined by 362 basis points from 6.22 per cent in January to 2.60 per cent in June 2009 which reflected the significant build-up of excess liquidity in the financial system. Commercial banks excess reserves averaged \$1,890 million over the period January to May 2009 compared to only \$250 million during the same period a year earlier.

2010.2-3: Drought at the start of the year and subsequent flooding adversely affected the supplies of locally grown produce causing an acceleration in headline inflation which reached 13.7 percent in June and peaked at 16.2 percent in August − the highest year-on-year rate since November 1983 − before moderating in the latter months of 2010. Food price increases, which measured 31.1 percent in June, accelerated to 39.1 percent in August and then slowed to 29.5 percent by December − the year-on-year increase in the price of fruits and vegetables reached 48.0 percent and 51.9 percent respectively in June 2010.

2011.3-4: Policy imposed curfew that lasted from August 21st, to December 5th, 2011.

2013.3: The Economic Bulletin reported that international cereal production rebounded due to increased acreage under production in traditional producers such as Brazil, Russia, and the United States. Locally in 2013 there were fewer weather related disruptions compared to the previous year; and there were less regional disruptions in the supply of fruits, in particular bananas.

2014.3: During third quarter of 2014 oil prices began declining. This decline continued into early 2015 where prices sat at record lows for the decade.

2014.4: Food inflation accelerated sharply since July 2014 − vegetable prices rose by 17.3 percent in October 2014. Evidence suggests that the cessation of planting at Caroni Green negatively impacted the supply of vegetables in the 2014.3 placing upward price pressures on this sub-category.

2015.4: On December 16, 2015 the Fed announced its first policy rate increase since the onset of the global financial crisis.

2015.4: In the first ten months of 2015 the CBTT sold just under US$2.5 billion to authorized dealers, which stands as the highest level of foreign exchange intervention on record.

9.2 Data Appendix

This appendix details the data, their sources, and notes caveats about their measurement. The data are quarterly and the sample period is 1996.1 to 2015.4 unless otherwise noted. The series are listed alphabetically by series symbol.

The data sources are the Central Bank of Trinidad and Tobago's Economic Bulletin, the IMF's International Financial Statistics (IFS) data base and the US Energy Information Administration. Data from the Economic Bulletin are from various issues, with data for any given observation taken from the most recent issue. Data from the IFS and EIA are from the online data bases. Each description includes the name of the series as it appears in the source publication, the definition, units, the source publication and the transformation used in estimation.

- Notation: P
  Name: TT retail price index
  Definition: TT consumer/retail price index
  Units: Index, average of four quarters of 2010 = 100
  Source: International Financial Statistics
  Transformation: $p = log(P)$,

- Notation: P*
  Name: US consumer price index
  Definition: US consumer price index.
  Units: Index, average of four quarters of 2010 = 100
  Source: International Financial Statistics
  Transformation: $p^* = log(P^*)$,

- Notation: PO
  Name: $US West Texas Intermediate (WTI) price per barrel.
  Definition: Cushing, OK WTI Spot Price FOB
  Units: US$ per Barrel, last month of quarter
  Source: US Energy Information Administration
  Transformation: $po = log(PO)$,

- Notation: RB
  Name: TT 3-month Treasury-bill rate
  Definition: TT Treasury Bill rate in percentage
  Units: Percentage
  Source: International Financial Statistics
  Transformation: $Rb = RB/400$,

- Notation: RB*
  Name: US 3-month Treasury-bill rate
  Definition: US Treasury Bill rate in percentage

Units: Percentage
Source: International Financial Statistics
Transformation: $Rb^* = RB^*/400$,

- Notation: SS
  Name: $TT/$US nominal exchange rate, selling rate
  Definition: $TT per $US
  Units: $TT
  Source: Economic Bulletin
  Transformation: $ss = log(SS)$.

9.3 CVAR with exogenous oil price

This appendix presents the long-run analysis of the fourth-order CVAR conditioned on the oil price. Table 5 presents results of the cointegration analysis. Formal tests results suggests there is at least one cointegrating vector and at most three. Specifically, the standard trace and maximum eigenvalue test statistics suggest there are three cointegrating relations and the respective degrees of freedom corrected statistics suggest there are two and one cointegrating vectors respectively. The first eigenvector clearly contains the interest rate differential relation between the domestic and foreign interest rates Rb and Rb^* respectively and seems augmented by a long-run exchange rate relation, the oil price and the regime shift in monetary policy. The second and third eigenvectors partly resemble the interest rate differential relation regarding the coefficient signs, however, the discrepancy in the coefficient estimates suggests this relation may not hold.[31] Altogether, interpretation of the eigenvectors suggests there is at least one long-run relation and perhaps a second that is a function of the second and third eigenvectors.

Table 6 presents the time series properties of the individual stochastic variables and structural hypothesis tests. The top panel presents the stationarity, H_{sta}, weak exogeneity, H_{we}, and variable significance, H_{sig} test results that indicate that none of the variables are stationary; all are individually significant to the long-run relation, save for the regime dummy albeit barely with a p-value of 0.087; and all are weakly exogenous save for the exchange rate and foreign prices.

[31] Note the second and third eigenvalues are numerically close and may suggest a linear function of the respective cointegrating vectors may yield an economically meaningful cointegrating relation, see Juselius (1998).

9.4 Short-run results, non-zero restrictions not imposed

This appendix presents the VEqCM prior to imposing non-zero parameter restrictions. Figure 12 presents the recursive estimates, the 1-step residuals and the 1-step ahead Chow statistics[32]

$$\begin{aligned}
\text{dss} = \; & \underset{(0.015)}{0.067}\ \text{dp}_{t-3} + \underset{(0.035)}{0.11}\ \text{dp*}_{t-2} + \underset{(0.15)}{0.68}\ \text{dRb}_{t-2} \\
& + \underset{(0.25)}{0.77}\ \text{dRb*}_{t-1} - \underset{(0.3)}{1.3}\ \text{dRb*}_{t-3} - \underset{(0.26)}{0.79}\ \text{dRb*}_{t-4} \\
& + \underset{(0.0019)}{0.0053}\ \text{dpo}_{t} - \underset{(0.0011)}{0.003}\ \text{dpo}_{t-4} - \underset{(0.0017)}{0.013}\ \text{Dat}_{t} \\
& + \underset{(0.00097)}{0.016}\ \text{Dsr}_{t} - \underset{(0.038)}{0.26}\ \text{ecm_f}_{t-1} + \underset{(0.1)}{0.69} \\
& - \underset{(0.00065)}{0.00021}\ \text{CS}_{t} - \underset{(0.00067)}{0.0013}\ \text{CS}_{t-1} - \underset{(0.00062)}{0.00059}\ \text{CS}_{t-2}
\end{aligned} \tag{9.1}$$

$$\begin{aligned}
\text{dpo} = \; & - \underset{(0.15)}{0.89}\ \text{I:2008(4)}_{t} - \underset{(0.15)}{0.41}\ \text{I:2014(4)}_{t} + \underset{(0.017)}{0.026} \\
& + \underset{(0.05)}{0.12}\ \text{CS}_{t} + \underset{(0.05)}{0.084}\ \text{CS}_{t-1} + \underset{(0.05)}{0.057}\ \text{CS}_{t-2}
\end{aligned}$$

log-likelihood = 431.30 -T/2log|Omega| = 644.14
no. of observations = 75 no. of parameters = 21
LR test of over-identifying restrictions: $\chi^2(59) = 133.36^{**}$ [0.000]

[32] It is important to note that the majority of the rejection of the LR test of over identifying restrictions is due the restrictions placed on the oil price equation. Specifically, restricting the system to the exchange rate equation and the identity results in the following statistics:

log-likelihood = 389.34 -T/2log|Omega| = 495.76
no. of observations = 75 no. of parameters = 15
LR test of over-identifying restrictions: $\chi^2(26) = 37.010$ [0.073]

9.5 Tables and Figures

Table 1: F and related statistics for the sequential reduction from a fifth to first-order VAR
The sample is 1997(2)-2015(4) for 75 observations
Computed with a constant, centered seasonal dummies and regime dummies (D_{cp}, D_{ff}, D_{at} and D_{sr} and D_{pr}.)

Null				Maintained			
System	k	λ	$SC/HQ/AIC$	$VAR(5)$	$VAR(4)$	$VAR(3)$	$VAR(2)$
VAR(5)	258	2092.85	-40.96/-45.75/-48.93				
↓							
VAR(4)	222	2032.86	-41.43/-45.55/-48.29	1.481			
				[0.060]			
↓				(36,121)			
VAR(3)	186	1973.39	-41.92/-45.37/-47.66	1.688**	1.784**		
				[0.004]	[0.009]		
↓				(72,152)	(36,147)		
VAR(2)	150	1939.48	-43.08/-45.87/-47.72	1.561**	1.494*	1.105	
				[0.005]	[0.017]	[0.328]	
↓				(108,161)	(72,185)	(36,174)	
VAR(1)	114	1855.71	-42.92/-45.04/-46.45	2.245**	2.237**	2.363**	3.691**
				[0.000]	[0.000]	[0.000]	[0.000]
				(144,165)	(108,196)	(72,217)	(36,200)

Table 2: Unrestricted cointegration analysis of time series data
The sample is 1997(2)-2015(4) for 75 observations
Computed with a constant, centered seasonal dummies and regime dummies (D_{cp}, D_{ff}, D_{at} and D_{sr} and D_{pr}.). All deterministic terms except D_{pr} are set unrestricted in the cointegration space.

$Hypotheses$	$r=1$	$r=2$	$r=3$	$r=4$	$r=5$	$r=6$
$Eigenvalues$	0.667	0.425	0.257	0.175	0.108	0.023
λ_{trace}	171.05** [0.00]	88.51** [0.00]	47.03 [0.06]	24.76 [0.18]	10.29 [0.27]	1.73 [0.19]
λ_{max}	82.54** [0.00]	41.48** [0.00]	22.28 [0.21]	14.47 [0.34]	8.56 [0.33]	1.73 [0.19]
λ^a_{trace}	116.31** [0.00]	60.19 [0.23]	31.98 [0.62]	16.83 [0.66]	7.00 [0.58]	1.17 [0.28]
λ^a_{max}	56.12** [0.00]	28.20 [0.21]	15.15 [0.74]	9.84 [0.76]	5.82 [0.64]	1.17 [0.28]
$Eigenvectors\ \beta$						
p	1	-0.452	0.043	0.074	-0.028	3.240
$p*$	-3.799	1	-0.147	-0.164	0.278	-11.56
ss	-16.98	0.159	1	0.103	-0.519	15.46
Rb	-15.60	4.402	-3.339	1	-0.315	5.877
$Rb*$	17.58	-1.038	3.874	-1.225	1	-71.61
po	0.247	0.061	-0.013	0.012	-0.032	1
D_{pr}	-0.150	0.029	0.038	0.031	-0.007	0.451
$Weights\ \alpha$						
p	0.011	0.251	-0.166	0.031	0.321	0.000
$p*$	0.006	0.037	0.052	-0.284	-0.082	0.003
ss	0.015	-0.002	0.020	-0.214	0.049	-0.000
Rb	0.003	0.001	0.032	0.070	0.017	0.000
$Rb*$	-0.002	-0.008	-0.012	-0.035	0.020	0.000
po	-1.147	0.301	5.336	-13.47	0.540	0.039

Table 3: Tests on the cointegration vectors with $r = 1$ imposed

Hypotheses	p	p^*	ss	Rb	Rb^*	po	D_{pr}	α_1	$\chi^2(v),(v)$	*p-value*
H_{sta}	72.68**	71.16**	41.17**	76.65**	76.12**	64.49**			,6	
H_{we}	0.337	0.550	17.93**	2.966	2.281	16.91**			,1	
	[0.562]	[0.458]	[0.000]	[0.085]	[0.131]	[0.000]				
H_{sig}	8.139**	15.15**	40.97**	9.214**	8.503**	12.71**	1.850		,1	
	[0.004]	[0.000]	[0.000]	[0.002]	[0.004]	[0.000]	[0.174]			
H_{1r}	1	-1	-1	0	0	0	0		75.55(6)	0.000
H_{1u}	1	-1	-1	-7.700	-5.407	-0.447	-0.221		42.31(2)	0.000
H_{2r}	0	0	0	1	-1	0	0		67.51(6)	0.000
H_{2u}	-0.074	0.274	1.092	1	-1	-0.017	0.009		0.492(1)	0.483
H_{3s}	-0.071	0.258	1	1	-1	-0.015	0.009		0.561(2)	0.756
H_{3sr}	-0.078	0.281	1	1	-1	-0.017	0		2.608(3)	0.456

Table 4: Long-run weak exogeneity tests (tested jointly with hypothesis H_{3s})

Hypotheses	$\chi^2(v),(v)$	p-value
H_{4p}: (0, *, *, *, *, *)	0.667(3)	0.881
H_{4p^*}: (*, 0, *, *, *, *)	1.058(3)	0.787
H_{4ss}: (*, *, 0, *, *, *)	18.94(3)	0.000
H_{4Rb}: (*, *, *, 0, *, *)	3.591(3)	0.309
H_{4Rb^*}: (*, *, *, *, 0, *)	2.523(3)	0.471
H_{4po}: (*, *, *, *, *, 0)	19.01(3)	0.000
H_5: (0, 0, *, 0, 0, *)	5.843(6)	0.441
H_6: (0, 0, *, *, 0, *)	3.494(5)	0.624
H_7: (0, *, 0, 0, 0, 0)	61.22(7)	0.000
H_8: (0, 0, *, 0, 0, 0)	36.01(7)	0.000
H_9: (0, 0, 0, 0, 0, *)	32.30(7)	0.000

Table 5: Unrestricted cointegration analysis of time series data
The sample is 1997(2)-2015(4) for 75 observations
Computed with a constant, centered seasonal dummies and regime dummies (D_{cp}, D_{ff}, D_{at} and D_{sr} and D_{pr}.). All deterministic terms except D_{pr} are set unrestricted in the cointegration space.

$Hypotheses$	$r = 1$	$r = 2$	$r = 3$	$r = 4$	$r = 5$
$Eigenvalues$	0.607	0.364	0.301	0.158	0.047
λ_{trace}	147.33** [0.00]	77.32** [0.00]	43.35** [0.00]	16.50* [0.03]	3.58 [0.06]
λ_{max}	70.01** [0.00]	33.97** [0.01]	26.85** [0.01]	12.92 [0.08]	3.58 [0.06]
λ^a_{trace}	108.04** [0.00]	56.70** [0.01]	31.79* [0.03]	12.10 [0.15]	2.63 [0.11]
λ^a_{max}	51.34** [0.00]	24.91 [0.11]	19.69 [0.08]	9.47 [0.25]	2.63 [0.11]
$Eigenvectors\ \beta$					
p	1	-0.745	0.533	0.116	0.017
$p*$	-3.835	1	-1.087	-0.367	-0.246
ss	-15.49	-3.776	1	0.991	1.156
Rb	-21.31	-3.574	-6.498	1	-2.197
$Rb*$	21.91	17.41	4.678	-1.655	1
po	0.338	-0.213	-0.058	0.013	-0.018
D_{pr}	-0.205	0.158	0.069	0.068	-0.042
$Weights\ \alpha$					
p	-0.023	0.033	-0.107	-0.195	-0.206
$p*$	0.033	-0.008	-0.069	0.124	0.003
ss	0.019	0.003	0.002	-0.085	-0.010
Rb	0.003	0.001	0.011	0.030	-0.017
$Rb*$	0.001	-0.004	-0.002	-0.012	-0.011

Table 6: Tests on the cointegration vectors with $r = 1$ imposed

$Hypotheses$	p	p^*	ss	Rb	Rb^*	po	D_{pr}	α_1	$\chi^2(v),(v)$	p-$value$
H_{sta}	48.87**	48.28**	53.62**	53.36**	53.82**	-				
H_{we}	1.681	15.44**	25.24**	3.229	0.933					
	[0.195]	[0.000]	[0.000]	[0.072]	[0.334]					
H_{sig}	7.243**	13.98**	29.42**	16.06**	11.20**	23.53**	2.939			
	[0.007]	[0.000]	[0.000]	[0.000]	[0.001]	[0.000]	[0.087]			
H_{1r}	1	-1	-1	0	0	0	0		52.24(6)	0.000
H_{1u}	1	-1	-1	-6.76	-19.45	0.85	-0.75		35.33(2)	0.000
H_{2r}	0	0	0	1	-1	0	0		50.24(6)	0.000
H_{2u}	-0.05	0.19	0.73	1	-1	-0.02	0.01		0.038(1)	0.846
H_{3s}	-0.06	0.22	1	1	-1	-0.02	0.01		1.113(2)	0.573
H_{3a}	-0.05	0.19	0.75	1	-1	-0.02	0.01		0.046(2)	0.977
H_{3h}	-0.05	0.21	0.87	1	-1	-0.02	0.01		0.394(2)	0.821
H_{3sr}	-0.07	0.25	1	1	-1	-0.02	0		3.234(3)	0.357
H_{3ar}	-0.06	0.21	0.72	1	-1	-0.02	0		3.266(3)	0.352
H_{3hr}	-0.056	0.23	0.85	1	-1	-0.02	0		2.991(3)	0.393

Figure 1: TT time series 1996.1-2015.4

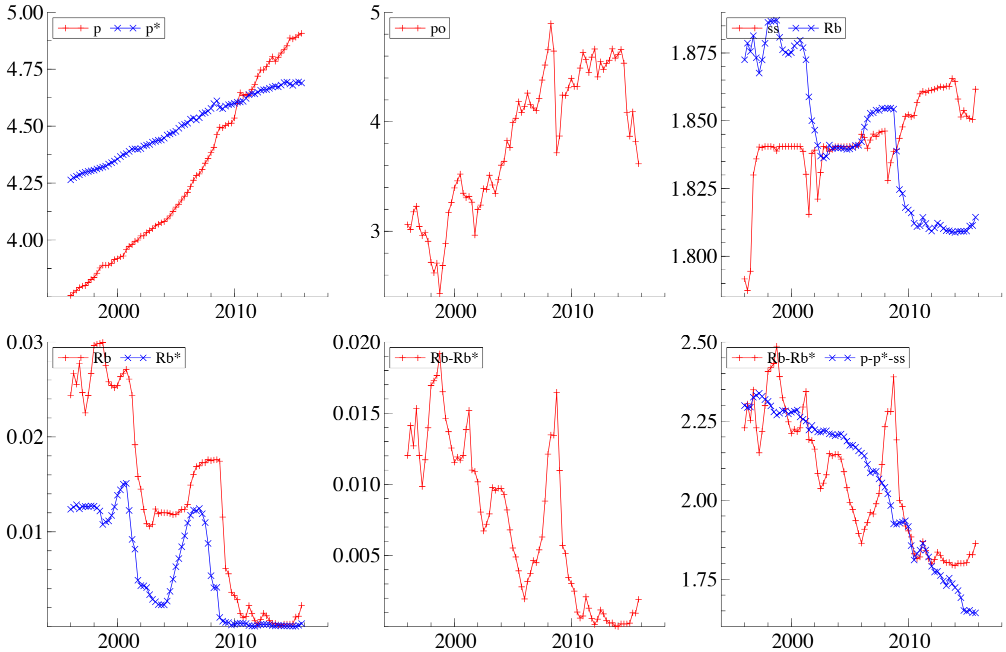

Figure 2: System graphical diagnostic statistics

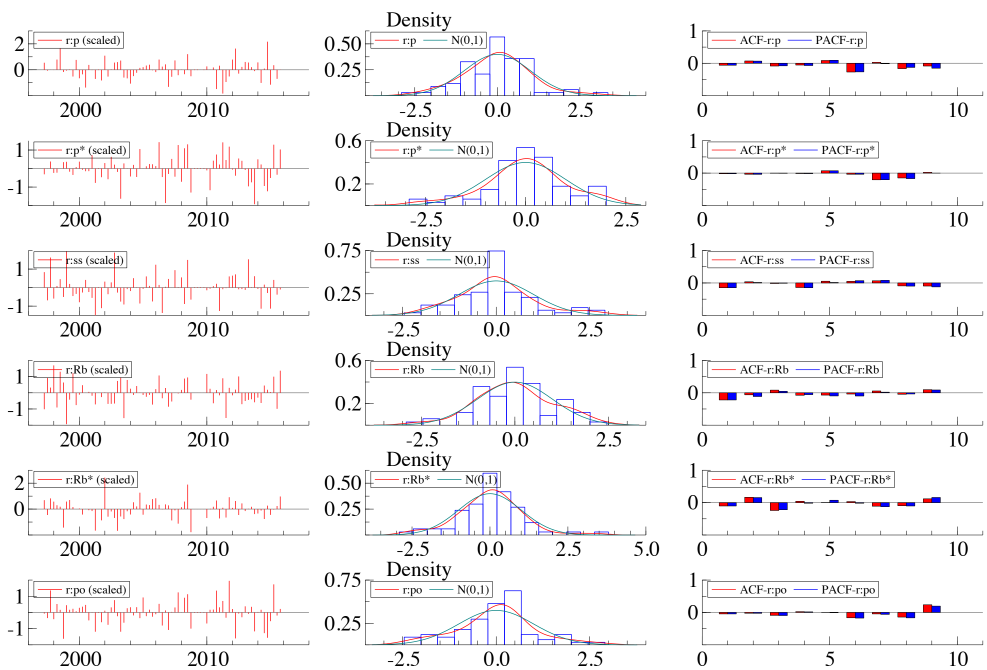

Figure 3: System graphical recursive statistics

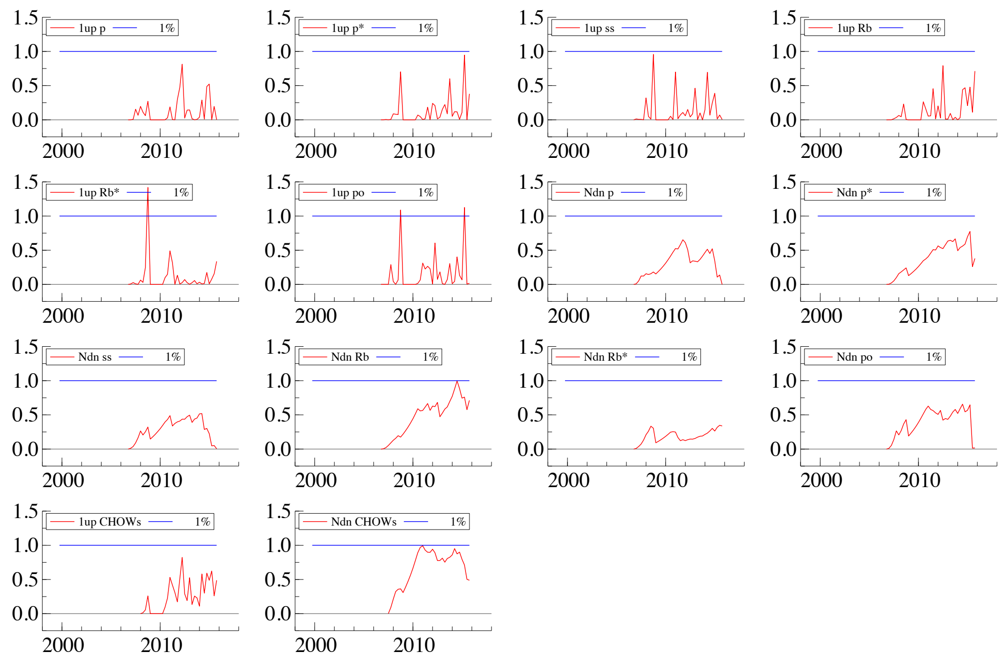

Figure 4: Recursive eigenvalues

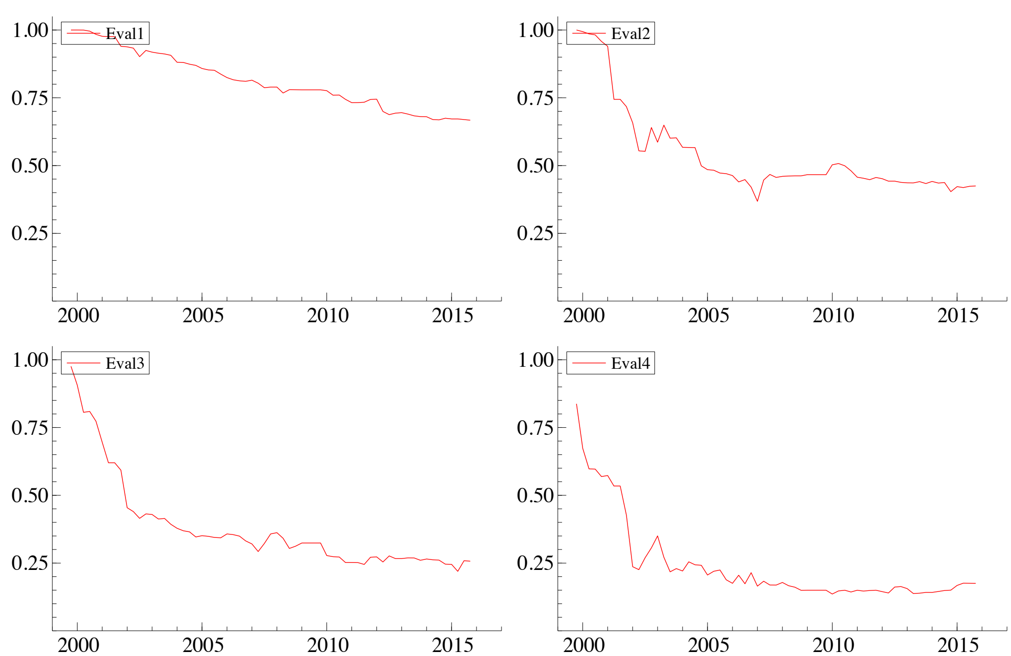

Figure 6: Graphical regression information (Parsimonious VEqCM)

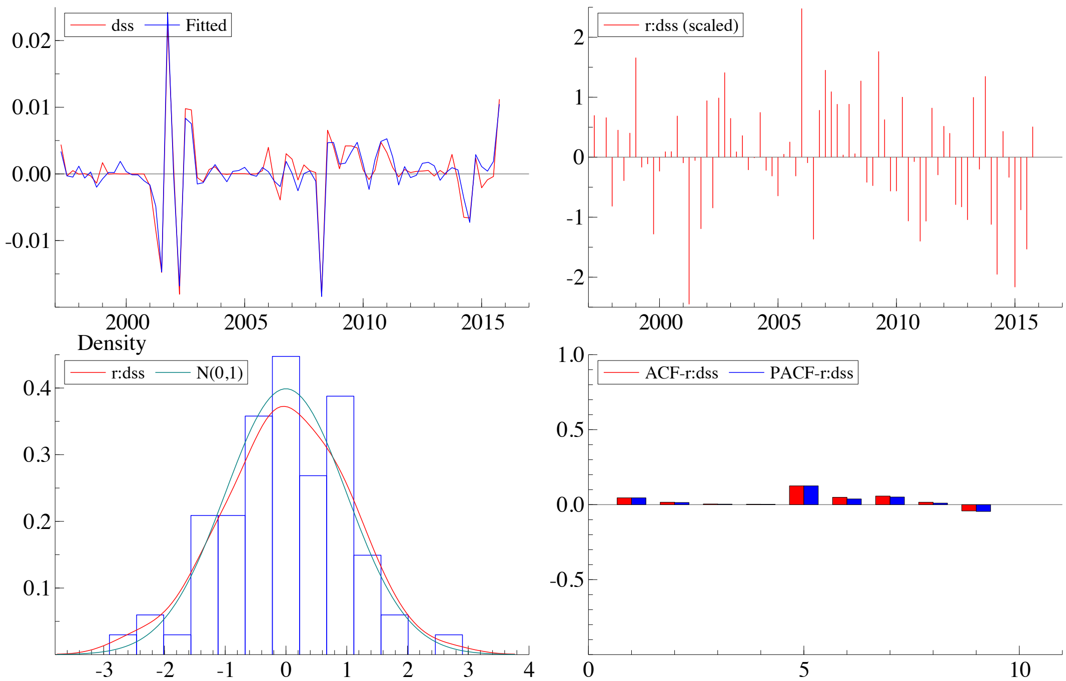

Figure 5: Unrestricted long-run relations, i.e. eigenvectors as defined in Table 2

Figure 7: Recursive FIML statistics Δss (Parsimonious VEqCM)

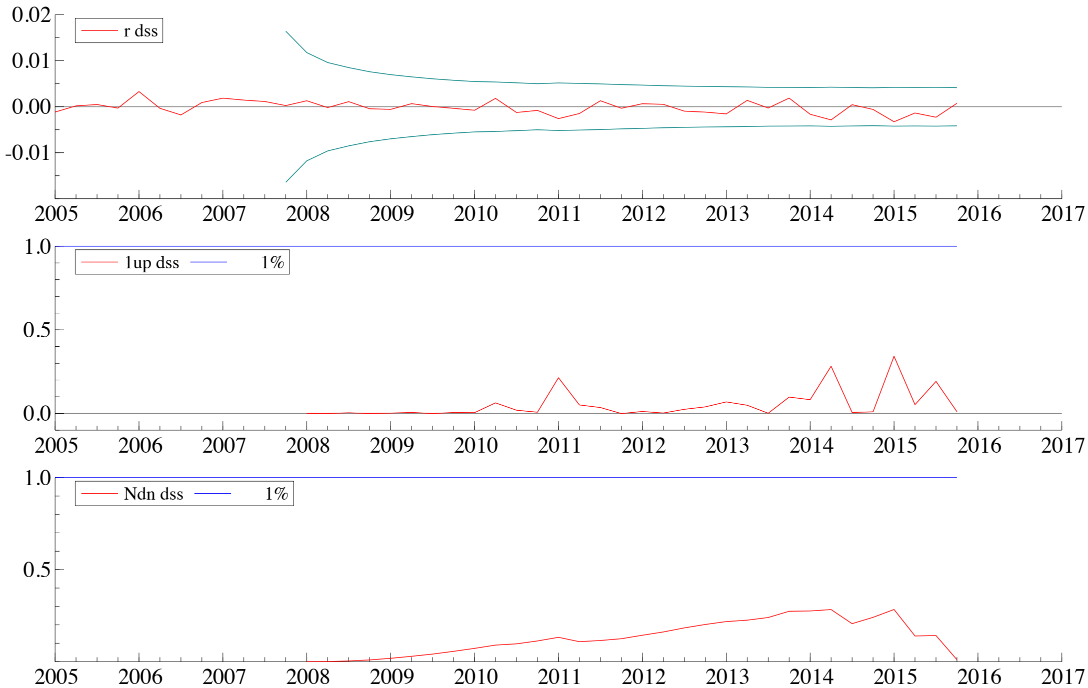

Figure 8: Recursive OLS statistics Δss (Parsimonious VEqCM)

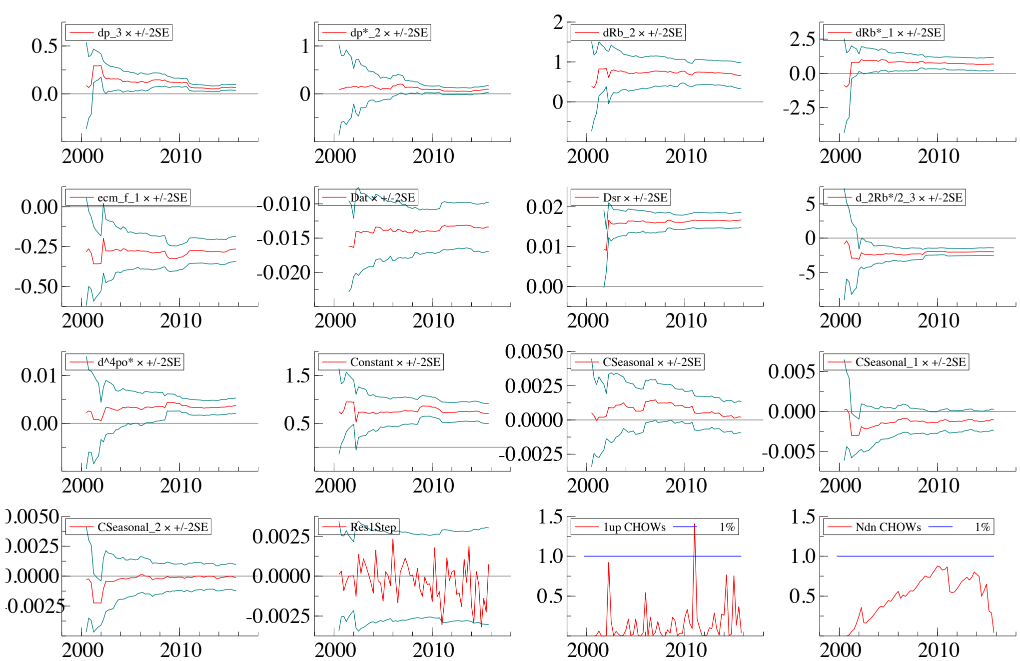

Figure 9: One-step residuals w/ $\pm\, 2\hat{\sigma}$ & Break-point Chows (p top row, p^* bottom row)

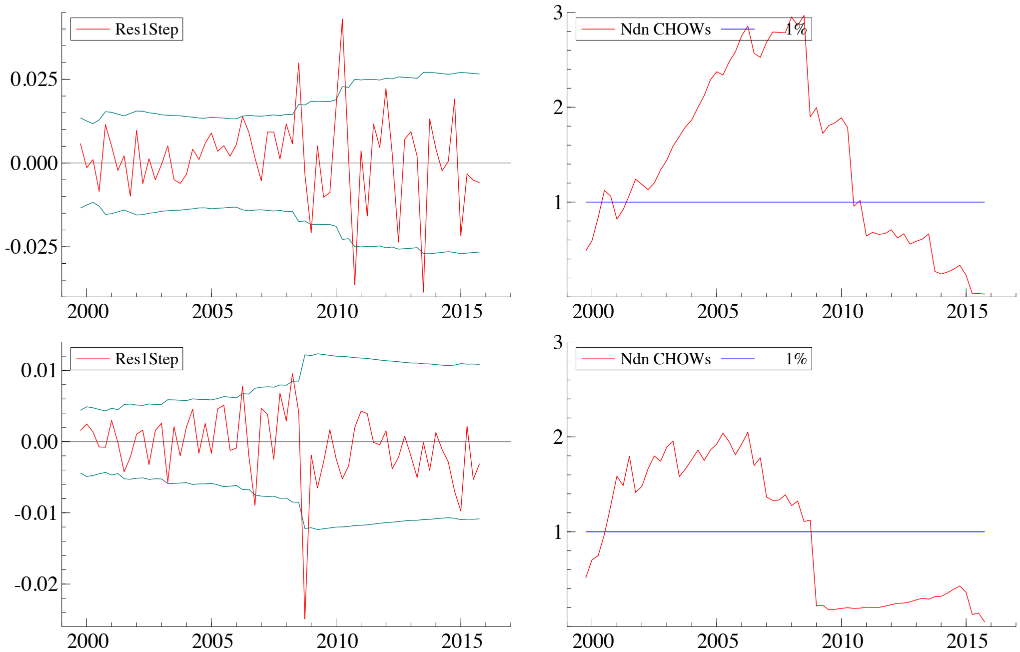

Figure 10: One-step residuals w/ $\pm\, 2\hat{\sigma}$ & Break-point Chows (Rb top row, Rb^* bottom row)

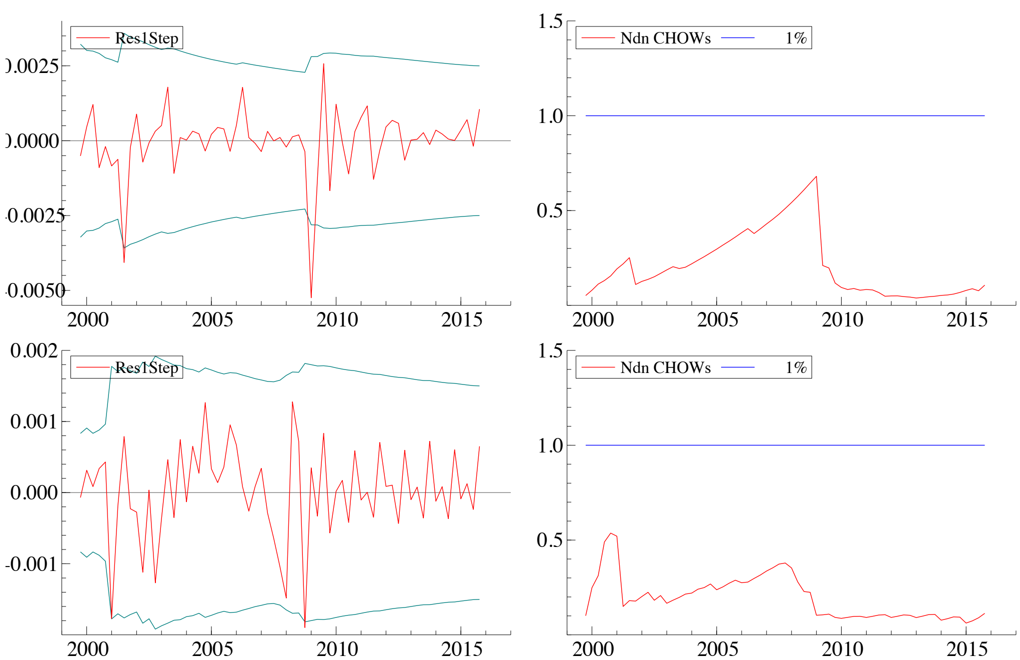

Figure 11: 1-step forecasts $\pm\, 2\hat{\sigma}$. Top row error variance only, bottom row w/ parameter uncertainty

Figure 12: Recursive OLS statistics Δss