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Abstract: This paper presents an approach for empirically estimating long-run monetary policy rules in small open economies. The approach utilizes the cointegrated VAR methodology and statistical tests on long- and short-run relations, and investigates policy responses. An application is presented for the case of Trinidad and Tobago. The analysis reveals an empirically supported long-run monetary policy rule for the nominal exchange rate, and provides empirical evidence that oil price shocks are transmitted through the TT economy in part via the effects on US prices. Dynamic specification of the nominal exchange rate reveals significant adjustment towards the *target* equilibrium level, and significant effects from foreign and domestic variables save for the exchange rate. Forecast analysis reveals the significance of oil-price forecasts, and forecast-errors, on monetary policy. The parsimonious model and its parameter estimates are empirically constant and generate reliable forecasts that provide important implications for using estimated policy rules.

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

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

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1 Introduction

This paper presents an approach for empirically estimating long-run monetary policy rules in small open economies. The approach utilizes the cointegrated VAR methodology, statistical tests on estimated long- and short-run relations, and investigates policy responses to deviations of macroeconomic variables from their target equilibrium levels. The hypothesized monetary 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. The estimated 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 macroeconomic variables. One plausible explanation for the difference is the marked variety of economic drivers among small open economies. For example, the main economic driver in the economy examined is the energy sector which determines the ability to earn valuable foreign exchange and attract international investment, say in the form of foreign direct investment (FDI).[1]

An application for Trinidad and Tobago is presented which makes several contributions to understanding how monetary policy is conducted in small open economies. First, it reveals an empirically supported long-run monetary policy rule for the TT dollar per US dollar nominal exchange rate. The cointegrating relation is among the domestic and foreign interest rate differential, the nominal exchange rate, domestic, foreign and oil prices and a regime dummy for the US Federal Reserve 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 establishes a dynamic specification for the TT dollar per US dollar nominal exchange rate. The dynamic specification is not autocorrelated, displays significant adjustment towards the estimated target equilibrium level, and significant effects from foreign and domestic prices and interest rates, and oil prices. Fourth, 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 and interest rates allowing for valid inference on policy simulations affecting the latter. Last, the dynamic specification produces forecasts with important implications for using estimated policy rules. In particular, the caveat that caution must be taken when nominal exchange rate equilibrium targets are reset and energy prices are mis-forecast.

This paper is organized as follows. Section 2 reviews the history of TT *exchange rate* monetary policy and the literatures relevant to TT monetary policy. Section 3 briefly describes the econometric methodology and empirical approach for estimating monetary policy rules. Sections 4 though 7 present the empirical application. Section 4 details the dataset and important events in the sample. Section 5 investigates the long-run multivariate properties of the data and interprets the policy rule. Section 6 presents the dynamic specification. Section 7 evaluates the model. Section 8 evaluates the forecasts and provides implications for using estimated policy rules. Section 9 concludes.

[1] Worrell (2012) highlights small *very* open which face foreign exchange constraints that are unaffected by exchange rate changes or other policies. These constraints have implications for monetary and exchange rate policy *inter alia*.

2 History and literature review

This section briefly reviews the monetary policy history and key macroeconomic literatures pertinent to TT. To garner a rich understanding of the TT macroeconomy knowledge of TT monetary policy history and the literatures on exchange rate modeling and forecasting, monetary policy rules, monetary policy transmission mechanisms, and the macroeconomic effects of energy price shocks in energy-exporting economies *inter alia* is imperative.

One common theme is reiterated throughout the following history and literature reviews, that is the unquestionable importance of the exchange rate to small open economies. In the discussions that follow the exchange rate is viewed as a target of monetary policy, an important transmission mechanism, an amplifier of fiscal shocks which may weaken the effects of monetary policy, and is imperative in explaining variation in output and other important macroeconomic variables.

2.1 Monetary policy history

The history of TT monetary policy is highlighted by a few key policy decisions surrounding the exchange rate. The Central Bank of Trinidad and Tobago (CBTT) originally pegged the TT dollar to the pound sterling at its introduction in 1964. The first key policy decision switched the exchange rate peg to the US dollar in 1976. Twice in the 1980s the TT dollar was devalued to the US dollar. The first was a 50 percent devaluation in December 1985 following the collapse in world oil prices of roughly the same magnitude. This was necessary to offset the relative loss in price competitiveness. The second devaluation occurred in August 1988 and was a *second* attempt to offset the loss in income and price competitiveness.[2]

On April 13, 1993, the CBTT decided to abolish exchange rate controls and abandon its fixed exchange rate with the US dollar. Though the CBTT opted for flexible exchange rate it was by no means intent on allowing it to float freely. Policy makers were concerned that a free-float would lead to uncertainty and unfavorable swings in macroeconomic conditions. This was the most important event thus far in CBTT history.

The decision to adopt a managed flexible exchange rate and the accommodating monetary policies implemented have since helped cement market expectations of a stable exchange rate. Managing the exchange rate has become one of if not the primary CBTT monetary policy objective and is openly communicated in the opening quote of the biannual monetary policy report which states,

"The CBTT conducts monetary policy geared towards the promotion of low inflation and a stable foreign exchange market that is conducive to sustained growth in output and employment ..."

[2] See Worrell et al. (2000) for a richer discussion on the exchange rate policy of Caribbean economies, and See Watson (2003a) and Farrell et al. (1994) for detailed reviews of the monetary policy history of TT.

2.2 Exchange rate modeling and forecasting

Several studies have developed TT exchange rate models for various purposes since the policy switch to a managed flexible exchange rate. The models include single equations in VAR models developed for evaluating monetary policy measures and mid-size structural econometric models developed for forecasting and policy analysis, see Watson (2003a, 2003b) for paradigms of the former, and Hilaire et al. (1990) and Watson and Teelucksingh (2001) for paradigms of the latter respectively. Typically, exchange rate specifications in the structural econometric models were autoregressive time-series models whereas the specifications in the VEqCMs were generally richer. The models developed thus far generally perform well in isolation within their respective forecast horizons.

Despite the VEqCM exchange rate specifications being richer than their time-series counterparts their relative forecast performances remain unexplored. Notably, forecast evaluation and "horse race" type studies have not received much attention in the Caribbean. This is perhaps due to a lack of competing reproducible models relative to advanced economies. Nonetheless, these studies are useful in their own right as they provide policymakers with irreplaceable insights into, *inter alia*, the relative forecast performance of available models which may have implications for forecast model averaging among a subset of models; and the evaluation of macroeconomic policy actions, i.e. counterfactual simulations. This inherent lack of forecast evaluation studies throughout the Caribbean has motivated the forecast analysis section of this paper.

2.3 Monetary policy rules

In a preliminary review of the monetary policy rule evaluation literature Taylor (2001) highlights one key stylized fact, namely that the exchange rate is an important part of the transmission mechanism in many of the policy-evaluation models. The review suggests that policy-evaluation research examining how the exchange rate should go into a monetary policy rule generally lend one of two conclusions: (i) that there are small performance improvements form directly reacting to the exchange rate, in addition to inflation and output, or (ii) that such reactions can make performance worse, see Taylor (1999), Ball (1999) Svensson (2000) and Galí and Monacelli (2002) among others. Taylor (2001) reiterates that it is not yet certain how the instruments of monetary policy should react to the exchange rate. In addition, the fact that the long-run equilibrium real interest rate and long-run equilibrium real exchange rate are not know in practice presents a difficulty with using such policy rules. In conclusion Taylor (2001) posits that there exists an indirect effect of the exchange rate on interest rates and output, via inertia combined with rational expectations, which may be responsible for the small improvement and sometimes worse performance of policy rules which incorporate exchange rate responses.

Ball (1999) finds that inflation targeting and Taylor rules are suboptimal in open economies unless they are modified significantly, and that different rules are required because monetary policy affects the economy through exchange rate as well as interest rate channels. The results suggest that policymakers seeking to minimize a weighted sum of output and inflation variances should have as their policy instrument a monetary conditions index (MCI) based on both the interest rate and the exchange rate, where the weight on the exchange rate is equal to or slightly greater than its relative effect on expenditure.[3] The latter result contrasts with those of Jacobson et al. (2001) who find that although both interest and exchange rates are central to the conduct of monetary policy an MCI may not be very useful and may be misleading. The analysis in Ball (1999) also suggests that policymakers seeking to minimize a weighted sum of output and inflation variances should choose ong-run inflations a target variable − an inflation variable purged of the transitory effects of exchange rate fluctuations.

Gali and Monacelli (2002) find a tradeoff between the stabilization of both the nominal and real exchange rates versus the stabilization of inflation and the output gap. In particular, the analysis reveals that a policy of domestic inflation targeting, which achieves a simultaneous stabilization of both domestic prices and the output gap, entails a substantially larger volatility of nominal and real exchange rates relative to a policy of consumer price inflation targeting and/or an exchange rate peg. This result suggests that domestic inflation targeting emerges as the optimal policy regime for a loss function that penalizes fluctuations in domestic inflation and the output gap as a consequence of the excess relative smoothing of real exchange rates of the alternative policies.

Santacreu (2015) analyzes the economic implications of two monetary policy rules, namely an exchange rate rule and a standard interest rate rule. Results indicate that the exchange rate rule outperforms the standard interest rate rule in lowering the volatility of key nominal and real economic variables only if the uncovered interest parity condition does not hold. The reasons for the lower volatility in the exchange rate rule is that the overshooting in the nominal exchange rate is avoided, and the risk premium that generates deviations from UIP is less volatile.[4]

2.4 Monetary policy transmission mechanisms

In their seminal paper on identifying monetary policy in small open economies Cushman and Zha (1995) found evidence in support of the exchange rate as an important transmission mechanism of domestic monetary policy shocks and foreign shocks in small open economies. Their results suggest that foreign shocks, such as foreign output shocks, affect domestic variables through the exchange rate where the impact of the foreign shock on the foreign interest rate dominates in affecting the exchange rate. Since their seminal work, several studies have reported similar results regarding the exchange rate as an important channel for the transmission of monetary policy.

Evidence supporting the exchange rate as an important monetary policy channel for TT has been reported by several authors, see Watson (2003a, 2003b), Ramlogan (2004, 2007) and Edwards (2015) among others. Watson (2003a, 2003b) developed VEqCMs to evaluate monetary policy measures on the real sector and the efficacy of monetary policy measures respectively. Both studies

[3]The rationale for using an MCI is that it measures the overall stance of policy, including the stimulus through both interest and exchange rates, where policymakers shift the MCI to ease or tighten monetary policy.

[4]The main difference between this rule and one in which the exchange rate is pegged to the currency of another country is that the central bank is able to react to fluctuations in real variables, such as the output gap, and so can achieve less volatile nominal variables without increasing the volatility of real variables, as would happen with a peg.

included the exchange rate as an endogenous variable in the system to account for the exchange rate transmission mechanism. The exchange rate specification of the latter study is richer as it includes effects from oil prices. The former study found *inter alia* that monetary policy measures do have an impact on the real sector and that the exchange rate is the most influential transmission mechanism of TT monetary policy. The latter study found that the applicability of monetary policy is limited to smoothing out minor economic fluctuations and that the tone of economic activity is set by the oil price.

Ramlogan (2004, 2007) examine the relative importance of the channels (money, credit and the exchange rate) through which monetary policy can affect economic activity for several Caribbean economies and TT respectively. Both studies share similar results. The former concludes that the credit and exchange rate channels are more important than the money channel in transmitting impulses from the financial sector to the real sector.[5] Notably, results indicate that exchange rate shocks are important in explaining output variability in Jamaica and TT by the end of the forecast horizon, but with different time profiles, where in TT they are relatively small initially but gain significance over the forecast horizon. The latter abstracts from examining the exchange rate channel and finds that credit channel dominates the money channel.

Edwards (2015) examines the nature of monetary policy transmission subject to foreign driven fiscal shocks. Foreign driven fiscal shocks are defined as net direct fiscal injections made possible as a result of energy price shocks. The results indicate that excess liquidity is a direct consequence of foreign driven fiscal shocks; and that high commercial banking spreads, which are driven by high excess liquidity, induces a financial attenuation mechanism that weakens the effect of monetary policy on the domestic economy.

Bjørnland (2008) analyzes the effects of monetary policy in Norway, an economy that shares similarities with TT. A structural VAR modified to allow for full simultaneity between monetary policy and the exchange rate, i.e. possible interdependence between the monetary policy stance and exchange rate movements was employed. Results indicate that contrary to other studies (cf. cite studies) a monetary policy shock now implies a strong and immediate appreciation of the exchange rate. Thereafter, the exchange rate gradually depreciates back to the baseline, which is consistent with both the Dornbusch overshooting hypothesis and UIP. Variance decompositions show that monetary policy shocks account for no more than 5 percent of the variation in the real exchange rate, output or inflation; and exchange rate shocks explain almost 90 percent of the exchange rate variation initially and also explains a modest share of the variance in the other variables.[6]

[5]This finding supports a priori expectations that in countries where the money market is relatively undeveloped the money market will not be the principal conduit of monetary policy shocks.

[6]Results also suggest that the exchange rate volatility with respect to monetary policy shocks increased when the Norges Bank formally switched from exchange rate targeting to inflation targeting in March 2001, while the contribution of monetary policy shocks to interest rate variation declined.

2.5 Macroeconomic effects of energy-price shocks

The key result emanating from the literature on the macroeconomic effects of energy-price shocks in energy-exporting economies suggests that asymmetric macroeconomic effects are commonplace but may differ significantly among small open energy-exporting economies. Specifically, the results indicate output growth is adversely affected by negative energy-price shocks, whereas energy sector booms or positive energy-price shocks play a limited role in stimulating growth. The asymmetric effects are exacerbated in heavily energy-dependent economies where fiscal expenditures are linked to current revenues.[7] The results reinforce the need for empirical investigation among small open economies with varying domestic and regional macroeconomic characteristics. More pertinent, these results call for investigation of monetary and fiscal policy rules and environments in these economies with emphasis on the potential asymmetric effects of energy price shocks.

Mehrara (2008) examined the asymmetric relationship between oil revenues and output growth in 13 oil-exporting countries. The empirical investigation utilized a dynamic panel framework and two different measures of oil-price shocks. Results for both oil-price shock measures suggest that positive oil revenue shocks have a transitory effect on real output with positive contemporaneous effects negated after one year. Conversely, negative oil-price shocks are more persistent and have a relatively larger effect on real output.

Lorde et al. (2009) empirically investigated the macroeconomic effects of oil price fluctuations on TT employing the cointegrated VAR methodology. Results indicate the oil price is a major determinant of TT economic activity and affects the macroeconomy asymmetrically. Notably, impulse response functions suggest output initially responds negatively to positive oil price innovations followed by a growing positive response, cf. Mehrara (2008). Abeysinghe (2001) attributes this short-term contractionary effect as being passed on through the net oil exporter's trading partners. In addition, variance decompositions suggest the oil price is a major component of forecast variation for most macroeconomic variables and Granger-causality tests indicate causality from oil prices to output and government revenue, where government revenue is the key channel through which oil prices affect the macroeconomy in the short run.[8]

Iwayemi and Fowowe (2011) empirically investigated the macroeconomic effects of oil price shocks on Nigeria employing the unrestricted VAR methodology. In contrast to Lorde et al. (2009) they find that for most macroeconomic variables in Nigeria, save for net exports, oil price shocks (i) do not have a major impact; (ii) do not Granger-cause; and (iii) account for only a small share of forecast variation. Similar to Lorde et al. (2009), however, they find asymmetric macroeconomic effects of oil price shocks and a short-term contractionary effect on output, albeit milder.

[7] These results generally extend to external shocks such as terms-of-trade and interest-rate changes, which have had substantial negative impacts on the Caribbean economies, see Gafar (1996).

[8] Granger-causality tests indicate causality from government revenue to net exports, government consumption and average prices, which suggests indirect causality from oil prices to these variables in the short-run.

3 Econometric methodology

This section details the econometric methodology and summarizes the empirical approach proposed for estimating monetary policy rules in small open economies.

3.1 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. The reasons 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

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

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

$$\Delta x_t = \pi x_{t-1} + \sum_{j=1}^{s-1} \Pi_j^* \Delta x_{t-j} + \Phi q_t + v_t. \tag{2}$$

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

$$\Delta x_t = \alpha\beta' x_{t-1} + \sum_{j=1}^{s-1} \Pi_j^* \Delta x_{t-j} + \Phi q_t + v_t. \tag{3}$$

3.2 Approach

The empirical approach is divided into three steps. Application of the relevant econometric tests are presented and detailed in Sections 4 through 7 during the empirical application.

Step 1: test for and identify cointegrating relations among macroeconomic and policy variables, and possible macroeconomic targets. Step 1 involves three parts: testing for cointegration among a system of macroeconomic and policy variables, testing structural hypotheses on the cointegrating vectors, and testing for weak exogeneity of possible macroeconomic target variables.

First, cointegration analysis is applied to a system of stochastic variables to determine the existence of at least one long-run relation. The stochastic variables are tested for individual significance in the cointegrating vector, in particular the policy and possible macroeconomic target variables.

Second, structural hypotheses are tested on the cointegrating vector to empirically assess economic theories hypothesized among the variables of the cointegrating vector. The assessment lends insight into the long-run economic theories that are supported and rejected by the data and assists in interpreting the cointegrating relations.

Third, the long-run weak exogeneity of possible macroeconomic targets is assessed. Rejection of weak exogeneity of macroeconomic variables indicates statistically that deviations of the cointegrating relation from its long-run equilibrium affects the short-run levels of these variables; and suggests the macroeconomic variables are possible targets. The latter is motivated by the ability of policymakers, via invariance of the policy variable, to adjust the policy variable in light of economic innovations to achieve desired long- and short-run levels of the macroeconomic targets.

Step 2: test for and establish invariance of macroeconomic targets to policy variables. Step 2 has two parts: dynamic specification of the possible macroeconomic targets identified in Step 1, and testing the invariance of the parameters of the dynamic specifications to changes in the marginal processes of the policy variables. First, a parsimonious and economically interpretable specification must be determined. Following *Gets* modeling, this involves specifying a general unrestricted model (GUM) that is then reduced to a final parsimonious specification. Second, super exogeneity, the conjunction of weak exogeneity and invariance, of the parameters of the dynamic specifications to the processes of the policy variables is tested. Failure to reject super exogeneity of the policy variables has two implications: it indicates valid inference on counterfactual simulations involving the policy variables are possible, and that policymakers *are* able to adjust the policy variables to achieve desired long-run equilibrium as well as short-run levels of the macroeconomic targets.

Step 3: identify corroborative policy responses to deviations from macroeconomic target levels. Step 3 ascertains whether policymakers are indeed using the estimated long-run relation as a policy rule. It involves investigating the policy responses to deviations of the macroeconomic targets from their respective long-run equilibrium levels. In particular, this step checks that the policy responses to deviations of the macroeconomic target from its long-run equilibrium are redirecting the target towards its old, or perhaps new, long-run equilibrium level. Identification of *corroborative* policy responses provides empirical evidence that the estimated long-run relations do indeed serve as policy rules among the macroeconomic and policy variables.

4 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) and oil price forecasts (FPO). 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 11.2 details the full dataset.

4.1 Major events during the sample period

Major events during the sample period are listed below and discussed in detail in Appendix 11.1:

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.

5 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.[9,10]

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-

[9] 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.

[10] Discussion of the system conditioned on the oil price is presented in Appendix 11.3.

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.[11] 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.[12]

Figure 1 plots various combinations of the log-levels of p, p^*, po, ss, Rb and Rb^* over the sample 1996.1−2015.4.[13] 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 (3.3) as follows:

$$\Delta x_t = \alpha\beta'(x', q_1)'_{t-1} + \sum_{j=1}^{s-1} \Pi_j^* \Delta x_{t-j} + \sum_{j=0}^{s-1} \Psi_j \Delta q_{1t-j} + \Phi q_{2t} + v_t, \tag{4}$$

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.

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.[14]

5.1 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.[15] 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

[11] 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.

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

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

[14] 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.

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

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 to 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.

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.[16] 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.

5.2 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

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

stationarity, H_{sta}, weak exogeneity, H_{we}, and individual significance in the cointegrating relation, H_{sig}.[17] 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 $\chi^2(4)$. These results suggest that inference on the system can be obtained from a model conditional on domestic and foreign prices and interest rates without loss of information.

Appendix 11.3 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.[18] The latter suggestion was investigated empirically by comparing the weak exogeneity results of both CVAR systems.[19] In particular, recall weak exogeneity of foreign prices is not rejected in the conditioned CVAR 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.

5.3 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

[17] 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.

[18] 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.

[19] 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 to the TT economy in part via its effects on foreign prices.

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 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.[20]

The result that the interest rate differential relation requires augmentation by the other variables indicates there exists a long-run relation among macroeconomic and policy variables. Together with the weak exogeneity test results, this result suggests that the CBTT may be following a policy rule for what is perhaps its most important macroeconomic target in the nominal exchange rate, ss. The opening quote of the Monetary Policy Report published by the CBTT dating as early as 2005 − as early as is published electronically − suggests that the central bank may seek to adjust the level of domestic interest rates relative to foreign interest rates if the nominal exchange and inflation rates deviate from their targets, ss_t^t, and Δp_t^t respectively, where the superscript t denotes targets.[21] The policy rule may also take into account deviations in foreign inflation from its target, Δp_t^{*t}, as foreign prices are known *a priori* to Granger-cause domestic prices; and deviations in oil prices beyond say a budgeted price, po_t^t, as the fiscal budget is based on *budgeted* 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 function:

$$Rb_t = Rb_t^* + a_1(ss_t - ss_t^t) + \Delta a_2(p_t - p_t^t) + \Delta a_3(p_t^* - p_t^{*t}) + a_4(po_t - po_t^t) + Rb_0 + u_t, \qquad (5)$$

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.[22]

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

[20]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.

[21]Note that nations aiming to target the rate of exchange rate depreciation will want to use Δss_t^t in place of ss_t^t.

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

case is restructured to include the levels of the domestic and foreign price series in place of their first differences and is as follows:[23]

$$Rb_t = Rb^*_t + a_1(ss_t - ss^t_t) + a_2(p_t - p^t_t) + a_3(p^*_t - p^{*t}_t) + a_4(po_t - po^t_t) + Rb_0 + u_t. \tag{6}$$

Empirical support for the hypothesized policy rule stated in (5.3) 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 monetary policy rule.

5.4 Interpreting the cointegrating relation

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

$$ecm_{f,t} = -0.071p_t + 0.258p^*_t + ss_t + (Rb_t - Rb^*_t) - 0.015po_t + 0.009D_{pr,t}. \tag{7}$$

Before this relation can be interpreted as a policy rule, however, the stochastic variables that adjust to disequilibrium in this relation must first be determined. Table 4 presents the weak exogeneity test results tested jointly with hypothesis H_{3s}. The results are similar to those of the unrestricted weak exogeneity tests and indicate that weak exogeneity of the cointegrating relation is *not* rejected for domestic and foreign prices and interest rates but is rejected for the exchange rate and oil prices. This suggests the cointegrating relation may be interpreted as a long-run monetary policy rule for the nominal exchange rate where it adjusts to disequilibrium in the long-run level; and where the CBTT, which has autonomy over its policy rate, may be able to adjust it to influence the long-run equilibrium as well as the short-run levels of the nominal exchange rate.[24]

The empirically supported cointegrating relation (5.4) provides insight into how the central bank may determine its policy interest rate when formulating monetary policy. Before interpreting the equilibrium relation, however, the error-correction term is defined by an identity as this representa-

[23] 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).

[24] It is important to note the current 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. The cointegrating relation is therefore neither interpreted as a policy rule for the oil price nor an long-run relation to which oil prices adjust to.

tion is more readily interpretable. The resulting transformation provides the *redefined* equilibrium relation as:

$$ecm_{f,t} \equiv ecm_{f,t-1} - 0.071\Delta p_t + 0.258\Delta p_t^* + \Delta ss_t + \Delta(Rb_t - Rb_t^*) - 0.015\Delta po_t + 0.009\Delta D_{pr,t}. \tag{8}$$

The cointegrating relation suggests that the CBTT may 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 may increase the spread on its policy rate relative to the foreign policy rate during crisis regimes.

The long-run coefficient estimates of the cointegrating relation have the *a priori* expected signs. 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 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 incomes/spending requiring the central bank to 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.[25] Raising the policy rate when the exchange rate appreciates below its target is in line with both UIP and Fisher open parity.

6 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 (5.5).[26] 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}. As was mentioned previously, 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.[27] In light of this an

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

[26] 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.

[27] 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.

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 dynamic exchange rate equation.

Equation (6.1) presents the FIML estimates of the final model and Figure 6 presents the graphical diagnostic statistics.[28] 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 except for the exchange rate.[29] In particular, the exchange rate depreciated 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.

$$
\begin{aligned}
\text{dss} \;=\;\; & \underset{(0.014)}{0.065}\ \text{dp}_{t-3} + \underset{(0.035)}{0.1}\ \text{dp*}_{t-2} + \underset{(0.16)}{0.67}\ \text{dRb}_{t-2} \\
& + \underset{(0.23)}{0.65}\ \text{dRb*}_{t-1} - \underset{(0.038)}{0.27}\ \text{ecm}_{f\,t-1} - \underset{(0.0017)}{0.013}\ \text{Dat}_t \\
& + \underset{(0.0009)}{0.017}\ \text{Dsr}_t - \underset{(0.28)}{2}\ \text{d}_2\text{Rb*}/2_{t-3} + \underset{(0.00076)}{0.0034}\ \text{d}^4\text{po}_t \\
& + \underset{(0.1)}{0.73} + \underset{(0.00056)}{0.00024}\ \text{CS}_t - \underset{(0.00064)}{0.001}\ \text{CS}_{t-1} - \underset{(0.00053)}{0.0001}\ \text{CS}_{t-2}
\end{aligned}
\tag{9}
$$

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.

[28] 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]

[29] 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.

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 equilibrium relation and domestic and external forces being the main determinants of the exchange rate. The latter result has become increasingly synonymous with small *very* open economies.

7 Model evaluation

The conditional model presented in (6.1) is evaluated on several criteria.[30] Section 7.1 tests the constancy of the model's estimates. Section 7.2 investigates the strong and super exogeneity of the marginal processes for the parameters of (6.1) and gives implications for these results regarding the Lucas critique, see Lucas (1976). Section 7.4 interprets the complete empirical model in light of the findings of the evaluation process.

7.1 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 reset in the *target* equilibrium level of the nominal exchange rate in 2011.1 may be appropriate.

The significance of the 2011.1 impulse dummy was tested in (6.1). 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

[30] It is important to note that the model is evaluated without the non-zero parameter restrictions imposed. This model is presented in Appendix 11.4. Imposing these restrictions, however, yields similar results.

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.

7.2 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.[31] 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 (6.1) 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.

7.2.1 The constancy test for super exogeneity

Marginal models for p, p^*, Rb and Rb^* are developed starting with fifth-order autoregressive models. Equations (7.1)−(7.4) 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.[32] 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 (6.1) 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.

$$\begin{aligned} \mathrm{dp} \;=\; & \underset{(0.12)}{0.25}\ \mathrm{dp}_{t-1} + \underset{(0.0023)}{0.011} \\ & - \underset{(0.0044)}{0.0021}\ \mathrm{CS}_t + \underset{(0.0043)}{0.00095}\ \mathrm{CS}_{t-1} + \underset{(0.0043)}{0.0021}\ \mathrm{CS}_{t-2} \end{aligned} \tag{10}$$

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

[31] Strong exogeneity ensures valid conditional forecasting and super exogeneity ensures valid policy simulations.
[32] Reductions from sixth-order autoregressive models led to the same marginal processes presented.

$$\begin{aligned} \text{dp*} &= \underset{(0.12)}{0.31}\ \text{dp*}_{t-1} - \underset{(0.12)}{0.26}\ \text{dp*}_{t-2} + \underset{(0.001)}{0.0051} \\ &\quad + \underset{(0.002)}{0.0065}\ \text{CS}_t + \underset{(0.0022)}{0.0084}\ \text{CS}_{t-1} + \underset{(0.002)}{0.0021}\ \text{CS}_{t-2} \end{aligned} \tag{11}$$

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

$$\begin{aligned} \text{dRb} &= \underset{(0.097)}{0.56}\ \text{dRb}_{t-1} - \underset{(0.00015)}{0.0001} - \underset{(0.00041)}{0.00038}\ \text{CS}_t \\ &\quad - \underset{(0.00041)}{4.4e-05}\ \text{CS}_{t-1} - \underset{(0.00041)}{0.0002}\ \text{CS}_{t-2} \end{aligned} \tag{12}$$

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

$$\begin{aligned} \text{dRb*} &= \underset{(0.1)}{0.6}\ \text{dRb*}_{t-1} + \underset{(0.12)}{0.35}\ \text{dRb*}_{t-3} - \underset{(0.11)}{0.35}\ \text{dRb*}_{t-4} \\ &\quad - \underset{(8.9e-05)}{6.3e-05} + \underset{(0.00025)}{0.0006}\ \text{CS}_t + \underset{(0.00025)}{0.0004}\ \text{CS}_{t-1} + \underset{(0.00026)}{0.00086}\ \text{CS}_{t-2} \end{aligned} \tag{13}$$

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

7.2.2 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 (7.5)−(7.8) present the improved marginal models with summary statistics displayed below each equation.[33]

$$\begin{aligned} \text{dp} &= - \underset{(0.0098)}{0.037}\ \text{I}_{13.3,t} - \underset{(0.0073)}{0.032}\ \text{S}_{08.2,t} + \underset{(0.0084)}{0.038}\ \text{S}_{08.4,t} \\ &\quad - \underset{(0.0086)}{0.05}\ \text{S}_{10.1,t} + \underset{(0.0092)}{0.062}\ \text{S}_{10.3,t} - \underset{(0.0059)}{0.021}\ \text{S}_{11.2,t} - \underset{(0.094)}{0.07}\ \text{dp}_{t-1} \\ &\quad + \underset{(0.0026)}{0.018} - \underset{(0.0031)}{0.00029}\ \text{CS}_t - \underset{(0.0031)}{0.00089}\ \text{CS}_{t-1} + \underset{(0.0031)}{0.00023}\ \text{CS}_{t-2} \end{aligned} \tag{14}$$

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

[33]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 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.

$$
\begin{aligned}
\text{dp}^* = \; & \underset{(0.088)}{0.38}\ \text{dp}^*_{t-1} - \underset{(0.089)}{0.14}\ \text{dp}^*_{t-2} - \underset{(0.0043)}{0.032}\ \text{I}_{08.4,t} \\
& + \underset{(0.00076)}{0.0044} + \underset{(0.0015)}{0.006}\ \text{CS}_t + \underset{(0.0017)}{0.008}\ \text{CS}_{t-1} + \underset{(0.0016)}{0.00067}\ \text{CS}_{t-2}
\end{aligned} \tag{15}
$$

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

$$
\begin{aligned}
\text{dRb} = \; & \underset{(0.075)}{0.38}\ \text{dRb}_{t-1} + \underset{(0.00098)}{0.0046}\ \text{S}_{01.2,t} - \underset{(0.00096)}{0.0046}\ \text{S}_{01.3,t} \\
& + \underset{(0.00072)}{0.0045}\ \text{S}_{08.4,t} - \underset{(0.00071)}{0.0045}\ \text{S}_{09.2,t} + \underset{(0.00018)}{3e-06} \\
& - \underset{(0.00031)}{0.0001}\ \text{CS}_t + \underset{(0.0003)}{0.00015}\ \text{CS}_{t-1} + \underset{(0.0003)}{4.6e-05}\ \text{CS}_{t-2}
\end{aligned} \tag{16}
$$

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

$$
\begin{aligned}
\text{dRb}^* = \; & \underset{(0.042)}{0.22}\ \text{dRb}^*_{t-1} - \underset{(0.00028)}{0.0016}\ \text{I}_{98.4,t} - \underset{(0.00031)}{0.0017}\ \text{I}_{07.4,t} - \underset{(0.00031)}{0.0027}\ \text{I}_{08.1,t} \\
& - \underset{(0.00028)}{0.0032}\ \text{I}_{08.4,t} + \underset{(0.00021)}{0.0029}\ \text{S}_{00.4,t} - \underset{(0.00034)}{0.0023}\ \text{S}_{01.2,t} + \underset{(0.00039)}{0.0027}\ \text{S}_{01.3,t} \\
& - \underset{(0.00029)}{0.0029}\ \text{S}_{01.4,t} - \underset{(0.00014)}{0.00096}\ \text{S}_{04.1,t} + \underset{(0.00016)}{0.0011}\ \text{S}_{06.3,t} - \underset{(0.00014)}{0.00035}\ \text{S}_{08.1,t} \\
& + \underset{(5e-05)}{7.4e-06} + \underset{(9.6e-05)}{0.00014}\ \text{CS}_t - \underset{(9.3e-05)}{0.00012}\ \text{CS}_{t-1} - \underset{(9.3e-05)}{3.1e-05}\ \text{CS}_{t-2}
\end{aligned} \tag{17}
$$

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

The invariance test results point to the invariance of the parameters in (6.1) to changes in the price processes, Δp and Δp^*, and 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 (6.1) 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 (6.1), is simply the combination of step dummies $S_{01.2}$ and $S_{01.3}$ in the improved marginal process for ΔRb.[34] The RHS variables of the ΔRb^* marginal process

[34] D_{at} was excluded from the invariance test as it is perfectly captured by the combination of $S_{01.2}$ and $S_{01.3}$.

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 invariance test results regarding ΔRb and ΔRb^{*} were highly influenced by the results of the regime dummy D_{at}, which can be viewed as a global one-off event. In light of this, the invariance tests were re-examined with regime dummy D_{at} omitted from the analysis. As anticipated, the invariance test results now point the invariance of the parameters in (6.1) to changes in the interest rate processes, ΔRb and ΔRb^{*}. Specifically, invariance of the RHS variables of the ΔRb marginal process is no longer rejected when tested jointly with an F statistic of F(2,58)= 2.141 and p-value of 0.127. Invariance of the RHS variables of the ΔRb^{*} marginal process is also no longer rejected when tested jointly with an F statistic of F(9,51)= 1.694 and p-value of 0.115. Joint testing of the invariance of the variables of ΔRb and ΔRb^{*} reported an F statistic of F(11,49)= 2.164 and p-value of 0.033; and joint testing of the invariance of these variables in addition to Δp snd Δp^{*} reported an F statistic of F(18,42)= 1.585 and p-value of 0.109.

The results of (*i*) and (*ii*) strongly suggest that the parameters (6.1) are invariant to changes in domestic and foreign price and 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 both the paths of price levels and interest rates, where in this case the latter are the primary instruments of monetary policy.[35] More generally, this result potentially has massive implications for a central bank that places immense emphasis on exchange rate stability.

7.3 Economic interpretation

The application provides empirical support for a stable long-run monetary policy rule for the nominal exchange rate involving the interest rate differential, the exchange rate, domestic, foreign and oil prices and a regime dummy for the Fed zero lower-bound monetary policy regime. The long-run homogeneous, i.e. one-for-one, 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. Review of the bi-monthly Monetary Policy Announcements supports this. 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

$S_{08.4}$, i.e. D_{pr} was also excluded since it was restricted to the cointegration space. t tests for its inclusion in the short-run specification were insignificant with a test statistic of -1.15 and p-value of 0.254.

[35] 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.

TT's ability to earn foreign exchange and global economic crises are also considered 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; and super exogeneity of domestic and foreign prices and interest rates is indicative that monetary policy can effectively target the exchange rate through manipulation of interest rates and if possible prices. The rejection of weak 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.

Policy responses to major events during the sample period, detailed in Appendix 11.1, supports the notion that the central bank is indeed using the policy interest rate, as well as other policy instruments and facilities, to influence the long-run equilibrium and short-run levels of the nominal exchange rate. The central bank has adjusted the policy rate effectively altering the interest rate differential and intervened at record levels in the foreign exchange market on several occasions in light of nominal exchange rate pressures.

These findings are all in accordance with communications by the CBTT regarding its conduct of monetary policy. Though the estimated policy rule is empirically supported 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 or compositions change. For these reasons, the empirically estimated policy rule presents only a first foray into estimating monetary policy rules in small open economies.

8 Forecast evaluation

This section evaluates the forecasts of the models developed in this paper and provides policy implications for using estimated monetary policy rules. The dynamic specifications of the alternative forecast models are presented and discussed in Appendix 11.5. The models are evaluated on three criteria. First, the models are evaluated for forecast accuracy as is measured by the root mean squared error (RMSE). Second, the models are evaluated on their ability to accurately predict the directional change in the exchange rate series. Third, the forecast models are evaluated for their ability to help explain the forecast-errors of the other models, i.e. forecast-encompassing.

8.1 Forecast performance

The forecasting exercise considers the forecast horizon 2014.1−2015.4. This forecast horizon requires re-estimating the models over the subsample 1997.2−2013.4 and using the re-estimated parameters to generate the forecasts. One-step ahead ex-post forecasts are generated and discussed.[36] Figures 11 and 12 display the one-step ahead forecasts of the four models in log first-differences and log-levels respectively. In both figures the top left panel displays the forecasts of model M1, the top right panel the forecasts of model M2, the bottom left panel the forecasts of the AR model and the bottom right panel the forecasts of the RW model.[37]

Table 7 presents the RMSE along with the mean and the standard deviation of the forecast-errors of the considered models. The results indicate that the equilibrium correction models M1 and M2 clearly outperform the time-series models AR and RW for the given forecast horizon with forecast RMSEs of 0.0023, 0.0022, 0.0053 and 0.0054 respectively. Between the equilibrium correction models, model M2 which incorporates oil price forecast-errors displays the potential to slightly improve upon model M1.

8.2 Directional accuracy

Table 8 presents the directional accuracy results of the one-step ahead forecasts of the four forecasting models. Visual inspection of Figure 11 suggests the forecasts of models M1 and M2 track the realized values of exchange rate changes fairly well − the majority of one-step ahead forecasts fall within the standard error bars and are near the realized values − whereas the forecasts of models AR and RW do not perform as well. Visual inspection of Figure 12, however, indicates that all models systematically over-forecast the level of the exchange rate, albeit by a quantitatively small value. Given the relative forecast performances, the following discussion will focus solely on the forecasts of the equilibrium correction models.

Directional accuracy results indicate that both models M1 and M2 perform well in 2014, successfully predicting three of four exchange rate changes. The accurately predicted changes notably include the relatively large appreciation in 2014.3 and subsequent depreciation in 2014.4 which represent the periods prior to and during the collapse of global energy price respectively.

Directional accuracy results are less impressive for 2015 with solely the relatively large depreciation of 2015.4 accurately predicted. This depreciation of the TT dollar per US dollar exchange rate was due largely to low inflows of foreign currency from the TT energy sector coupled with sustained demand for foreign currency.[38] The ability of models M1 and M2 to accurately predict the 2014.3, 2014.4 and 2015.4 appreciations and depreciations is suggestive of their robustness to energy market conditions. Their inability to accurately predict exchange rate appreciations during 2015.1-3, however, is suggestive that what appears as an equilibrium shift in the level of the exchange rate may not be well accounted for.[39]

[36] Multistep-ahead forecasting is not as straightforward as it requires generating forecasts of the dependent variables which may be an arduous task especially when considering the current information set.

[37] Note no location shifts are used in the forecasting exercise, and all forecasts standard errors are the error variances only and do not include parameter uncertainty.

[38] The low inflows of foreign currency from the energy sector were the result of low energy prices and lower than usual output levels due in part to prolonged infrastructural works at major domestic energy companies.

[39] Note visual inspection of the log-level of the exchange rate suggests a new *appreciated* long-run level as of late 2014 that appears to revert to the prior long-run level or perhaps a new depreciated level at the end of the sample.

Overall, the directional accuracy results of both equilibrium correction models suggest that they are capable of accurately predicting directional changes in the exchange rate, however, caution must be made in light of new, perhaps policy influenced, equilibrium levels of the exchange rate. Equilibrium level-shifts may be addressed by differenced VEqCMs or intercept correction (IC) for modeling and forecasting purposes respectively, see Ericsson and Marquez (1993) and Castle et al. (2013) among others.

8.3 Forecast encompassing

This subsection evaluates the ability of the four forecasting models to explain the forecast-errors of the other models. The evaluation utilizes the forecast-encompassing test of Chong and Hendry (1986) and the generalized test of Ericsson and Marquez (1993). Chong and Hendry (1986) propose regressing the forecast-errors of one model on the forecasts of another:

$$v_{T+s}^{(h)} = \kappa_l \mu_{T+s}^{(l)} + e_{T+s}^{(h)} \qquad s = 1, ..., S, \tag{18}$$

where $v_{T+s}^{(h)}$ is the actual forecast error of model h, $\mu_{T+s}^{(l)}$ is the forecast of model l where $(l \neq h)$ and $e_{T+s}^{(h)}$ is the error of the regression. The forecast-encompassing statistic is the t-ratio, or alternatively the F-value, on κ_l, and is $N(0,1)$ for large T and S when model h is correctly specified.

Ericsson and Marquez (1993) proposed a generalization to Chong and Hendry (1986) by allowing for (i) a constant term, which accounts for systematic forecast biases; (ii) comparison against several models at once, as opposed to just one; (iii) model nonlinearity; (iv) multi-step ahead forecasts from dynamic models; (v) and the uncertainty from estimating rather than knowing model coefficients. The regression accounting for (i) and (ii) is given by

$$v_{T+s}^{(h)} = \kappa_0 + \sum_{l \neq h} \kappa_l \mu_{T+s}^{(l)} + e_{T+s}^{(h)} \qquad s = 1, ..., S. \tag{19}$$

Eqs (8.1) and (8.2) are used to test for forecast-encompassing among the models being evaluated. Table 9 presents the pairwise and multi-model forecast-encompassing tests statistics. The pairwise forecast-encompassing test null hypotheses are $\kappa_l = 0; \kappa_0 \equiv 0$, $\kappa_l = 0$; and $\kappa_l = \kappa_0 = 0$, which test the regressions of Chong and Hendry (1986) and Ericsson and Marquez (1993) with the constant term unrestricted and restricted to equal zero respectfully. The multi-model forecast encompassing test null hypotheses are $\forall\kappa_l = 0; \kappa_0 \equiv 0$, $\forall\kappa_l = 0$; and $\forall\kappa_l = \kappa_0 = 0$, which test the multi-model extensions of the pairwise regressions proposed by Ericsson and Marquez (1993). Both the pairwise and multi-model test regressions test whether model(s) l is (are) encompassed by model h, i.e. whether the forecasts of model(s) l help explain the forecast of model h.

The pairwise test statistics suggests the mean forecasts from models M1 and M2 help explain the mean forecast errors of models AR and RW whether or not a constant term is included. The test statistics for the forecast of M1 explaining the forecast-errors of models AR and RW respectively are $[F(1,7) = 22.2, 22.9]$ when a constant is not included; $[F(1,6) = 61.2, 57.5]$ when a constant is included but not restricted to equal zero; and $[F(2,6) = 31.9, 29.7]$ when a constant is included but *is* restricted to zero. Similarly, test statistics for the forecast of M2 explaining the forecast-errors of models AR and RW respectively are $[F(1,7) = 23.6, 23.9]$, $[F(1,6) = 67.6, 60.4]$, and $[F(2,6) = 35.2, 31.3]$.

Pairwise test statistics also suggests that forecasts from model AR help explain the the forecast errors of model M2 when a constant term is included but is restricted to zero $[F(2,6) = 6.06]$; and that forecasts of model RW help explain forecast errors of models M1 and M2 when the constant term is omitted with test statistics $[F(1,7) = 6.15]$ and $[F(1,7) = 6.62]$ respectively. These results may suggest dynamic misspecification regarding autocorrelation in models M1 and M2 as autocorrelation is the only information in models AR and RW. However, the former results indicating both models AR and RW are forecast-encompassed by both models M1 and M2, along with the interpretation of the constant term in these tests suggests models M1 and M2 may suffer from *systematic* forecast biases and not necessarily from dynamic misspecification.

The multi-model test statistics provide similar results to the pairwise test statistics. Specifically, the results indicate the time-series models AR and RW are rejected, i.e. are forecast-encompassed, with test statistics $[F(3,5) = 19.6, 10.1]$ when a constant is not included; $[F(3,4) = 15.1, 35.4]$ when a constant is included but not restricted to equal zero; and $[F(4,4) = 11.8, 27.4]$ when a constant is included but *is* restricted to equal zero.

In summary, the pairwise and multi-model forecast-encompassing test results indicate that the forecasts of the equilibrium correction models have the ability to help explain the forecast-errors of the time-series models. At the very least, these results suggest that the dynamic specifications of the latter models lack important economic information, which is not surprising given their limited information sets. More interesting, however, these results have important implications for policy analysis utilizing estimated policy rules. First, the caveat that caution must be taken when equilibrium exchange rate targets are reset and energy prices are mis-forecast. Second, forecast-encompassing test results indicate models M1 and M2 neither encompass or are encompassed by the other model, and the failure of both models to forecast-encompass the other suggests the potential for forecast model improvement.

9 Concluding Remarks

This study presents an approach for empirically estimating monetary policy rules for small open economies. The approach utilizes the cointegrated VAR methodology, statistical tests on estimated long- and short-run relations, and investigates policy responses to deviations of macroeconomic variables from their target equilibrium levels. An application is presented for the case of Trinidad and Tobago and an empirically supported long-run monetary policy rule for the nominal exchange rate is found among the domestic and foreign interest rate differential, the exchange rate, domestic, foreign and oil prices and a regime dummy for the Federal Reserve zero lower-bound monetary policy regime.

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 towards the estimated target equilibrium level. Parameter estimates of the parsimonious VEqCM are empirically constant. Strong exogeneity is rejected for all stochastic variables. Super exogeneity is *not* rejected for foreign and domestic prices and interest rates indicating valid inference on policy simulations may be made regarding these variables, i.e., the model is suitable for policy analysis and selection where domestic and foreign prices and interest rate are concerned.

The forecast evaluation exercise considers four empirical models − two equilibrium correction models and two time-series models − and utilizes the forecast-encompassing test of Chong and Hendry (1986) and the generalized test of Ericsson and Marquez (1993). Forecast-encompassing test results suggest that the forecasts of the equilibrium correction models help explain the forecast errors of the time-series models. The failure of both equilibrium correction models to forecast-encompass the other suggests potential for model improvement among these models. Together, the predictive performance of the equilibrium correction models have implications for policy analysis using estimated policy rules, namely the caveat that caution must be taken when equilibrium exchange rate targets are reset and energy prices are mis-forecast.

The approach presented in this study is neither unique to TT nor monetary policy rules, and is in general potentially applicable to many small open economies as well as estimating fiscal policy rules. Several key economic features must be determined when applying this approach in other empirical investigations of monetary policy rules. First, measures for earning foreign exchange, for example, a commodity price for a small non-renewable natural resource economy and renewable commodity exporter, or foreign GDP for a region if tourism is the main economic driver. Second, the advanced economy the central bank monitors when making its monetary policy decisions, i.e. regarding policy rate decisions, inflation, growth, unemployment, etc. Third, the domestic central bank's available policy responses to shocks to variables considered in the policy rule, for example, interest rate differential adjustments, foreign exchange interventions, or exchange rate re/devaluations.

Applications of this approach to estimating fiscal policy rules may not be far removed. It is plausible that the key economic features that must be determined concern measures for earning government revenues, for example, rents from the extractive sectors or specific taxes; the ability of the central government to issue debt, i.e. its credit rating; and the available policy responses to innovations in domestic economic conditions, for example, unanticipated intra-year public subsidy adjustments, public wage and contract length revisions, or temporary tax rate adjustments.

Future research in estimating monetary and fiscal policy rules for small open economies may consider extending initial information sets to allow more variables potentially under consideration by the authorities to enter the policy rule, and using comprehensive measures of the ability to earn foreign exchange or government revenue. One worthwhile extension may potentially focus on investigating the timing and sources of changes in estimated 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. Another worthwhile extension may investigate the presence of asymmetries in the estimated monetary and fiscal policy rules, particularly as it relates to exogenous foreign shocks.

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11 Appendix

11.1 Political interventions, regime shifts, crises and major events

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

2001.1: US Federal Reserve 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 Federal Reserve expansionary monetary policy.

2008.2: The appreciation of the TT dollar vis-à-vis the US dollar 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 Royal Bank of TT and Royal Bank of Canada.

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 Federal Reserve 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. This lead to 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 from 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 2014.3 placing upward price pressures on this sub-category.

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

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

11.2 Data Appendix

This appendix has two objectives. First, it details the data, their sources, and notes caveats about their measurement. Second, it describes the methodology used to generate the missing observations for the WTI oil price forecasts series, i.e. for the sample period 1996.1−2003.2.

11.2.1 Data description

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 (EIA). 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 are from the online data bases. Data from the EIA are from both the online data bases and the Short Term Energy Outlook (STEO) publications, where data from the latter reference the last monthly publication of each quarter. 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: FPO

  Name: $US West Texas Intermediate (WTI) price per barrel forecast.
  Definition: Cushing, OK WTI spot price FOB forecast
  Units: US$ per Barrel, last month of quarter
  Source: US Energy Information Administration Short Term Energy Outlook
  Transformation: $fpo = log(FPO)$,

- 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: PO/FPO
  Name: $US West Texas Intermediate (WTI) price per barrel forecast error.
  Definition: Constructed as PO/FPO = PO / FPO
  Units: US$ per Barrel, last month of quarter
  Source: Not applicable
  Transformation: $po - fpo = log(PO/FPO)$,

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

11.2.2 Generating missing oil price forecasts

A VAR model in first-differences of natural logs is used to generate the missing observations for the WTI oil price forecasts series, FPO, for the period 1996.1−2003.2. The specification of the 3-variable VAR includes the WTI average spot price, the refiner average acquisition cost, and the imported average price series sourced from the US EIA STEO publications; and 5 lags based on the results of the Augmented Dickey Fuller (ADF) tests for lag length testing for a model starting with 12 lags. Note, it is assumed that the level of econometric modeling at the EIA at the time did not allow for cointegration testing and recursive model testing for stability, thus these techniques are not performed when selecting the forecasting models.

The procedure for generating the forecasts is as follows. First, the initial estimation sample of 1991.02−1995.12 is used to generate three monthly one-step ahead forecasts. Second, the forecasts from the VAR model in first-differences of natural logs are transformed into levels to get the forecast in levels, i.e. in US dollars per barrel. Third, the estimation sample is updated to include the actual values from 1991.02 through to the last month previously forecasted. This process is reiterated until the all missing forecast observations are generated.

11.3 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.[40] 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. The results 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.

Each hypothesis investigated in the mid panel of Table 6 was retested with the added restriction that the coefficient on the regime dummy equals zero. These results are presented in the bottom panel of Table 6. The results are for the most part unchanged and reaffirm the prior results, albeit

[40]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).

with the minor caveats. In particular, hypothesis H_{3hr} now has a p-value of slightly larger than that of H_{3ar} and H_{3sr}, 0.393, 0.357 and 0.352 respectively. The large all-round reduction in p-values when a zero restriction is imposed on the coefficient of the regime dummy, however, suggests that despite being *barely* insignificant the regime dummy contributes considerable and perhaps useful information to the long-run relation.

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

This appendix presents the VEqCM of model M1 prior to imposing non-zero parameter restrictions. Figure 12 displays the recursive estimates, the 1-step residuals and 1-step ahead Chow statistics[41]

$$\begin{aligned}
\text{dss} = {} & \underset{(0.015)}{0.067}\ \text{dp}_{t-3} + \underset{(0.035)}{0.11}\ \text{dp*}_{t-2} + \underset{(0.15)}{0.68}\ \text{dRb}_{t-2} \\
& + \underset{(0.25)}{0.77}\ \text{dRb*}_{t-1} - \underset{(0.3)}{1.3}\ \text{dRb*}_{t-3} - \underset{(0.26)}{0.79}\ \text{dRb*}_{t-4} \\
& + \underset{(0.0019)}{0.0053}\ \text{dpo}_{t} - \underset{(0.0011)}{0.003}\ \text{dpo}_{t-4} - \underset{(0.0017)}{0.013}\ \text{Dat}_{t} \\
& + \underset{(0.00097)}{0.016}\ \text{Dsr}_{t} - \underset{(0.038)}{0.26}\ \text{ecm_f}_{t-1} + \underset{(0.1)}{0.69} \\
& - \underset{(0.00065)}{0.00021}\ \text{CS}_{t} - \underset{(0.00067)}{0.0013}\ \text{CS}_{t-1} - \underset{(0.00062)}{0.00059}\ \text{CS}_{t-2}
\end{aligned} \tag{20}$$

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

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]

11.5 Alternate forecast models

This appendix presents the dynamic specifications of the alternate forecast models considered in the forecasting exercise. The first alternate forecast model considered, model M2, augments the dynamic specification of model M1 to incorporate information from oil price forecast-errors. The

[41] 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]

available information set for includes (Δp_{t-i}, Δp^*_{t-i}, Δss_{t-i}, ΔRb_{t-i}, ΔRb^*_{t-i}, Δpo_{t-i}, $(po-fpo)_{t-i}$) for $i = 0, ..., 4$, an intercept, centered seasonal dummies and regime dummies D_{cp}, D_{ff}, D_{at} and D_{sr}. The oil price forecast-error, $po - fpo$, is hypothesized to affect the macroeconomy in the short-run and so is included in the current information set. Inclusion of the forecast-errors allows us to test the hypotheses that deviations from market *expectations* of oil prices affects the current level of exchange rate, and affects exchange rate forecast accuracy.

Reduction from the GUM to the final parsimonious model mirrors the steps of model M1. Specifically, first the *Autometrics* algorithm of *PcGive* was applied;[42] and second, nonzero parametric restrictions were imposed to arrive at a more parsimonious and economically interpretable specification. The reductions result in the following dynamic specification:

$$\begin{aligned}\text{dss} \;=\;& \underset{(0.0148)}{0.0709}\ \text{dp}_{t-3} + \underset{(0.0289)}{0.137}\ \text{dp*}_{t-2} + \underset{(0.158)}{0.578}\ \text{dRb}_{t-2} + \underset{(0.195)}{0.582}\ \text{dRb*}_{t} \\ & - \underset{(0.0016)}{0.0149}\ \text{Dat}_t + \underset{(0.000919)}{0.0179}\ \text{Dsr}_t - \underset{(0.262)}{1.9}\ \text{d}_2\text{Rb*}/2_{t-3} \\ & + \underset{(0.000637)}{0.00266}\ \text{(po-fpo)}_t\text{-(po-fpo)}_{t-4t} - \underset{(0.0364)}{0.268}\ \text{ecm\_f}_{t-1} + \underset{(0.0967)}{0.712}\end{aligned} \tag{21}$$

log-likelihood $= 385.07$ $\quad R^2 = 0.93$ $\quad \sigma = 0.0015$
$T = 75$ $\quad$ no. of parameters $= 10$ $\quad AR : F(5, 60) = 0.12[0.9886]$
$ARCH : F(4, 67) = 0.269[0.8971]$ $\quad Normality : \chi^2(2) = 1.23[0.5400]$
$HeteroA : F(16, 57) = 1.63[0.0909]$ $\quad RESET : F(2, 63) = 0.73[0.4843]$

Diagnostic test statistics are reported below equation (11.2) and none of the statistics are rejected at standard levels. Altogether, the diagnostic statistics clearly indicate a statistically well specified good fit. Moreover, the recursive estimates depict empirically constant parameters and provide evidence of the model robustness. Parameter encompassing test statistics displayed in Table 10 suggest, however, that model M1 parameter encompasses model M2.

The benchmark alternate time-series models considered are the autoregressive and random walk models, AR and RW respectively. Dynamic specification of the autoregressive model is determined by applying the *Autometrics* algorithm of *PcGive* to an initial AR(4) model, whereas the specification of the random walk with drift model is determined by regressing the first-difference of the nominal exchange rate series on a constant. The resulting dynamic specifications of models AR and RW are presented respectively in Eqs (11.3) and (11.4):

$$\text{dss} = - \underset{(0.0906)}{0.223}\ \text{dss}_{t-2} + \underset{(0.000599)}{0.00051}, \tag{22}$$

[42]The following *Autometrics* settings were used: target size was set to 0.10; no outlier and break detection; no pre-search lag and variable reduction; search effort was set to 1; backtesting was set to GUM 0; the tie breaker was the Schwarz Criterion; diagnostic test *p-value* was set to 0.01; and GIVE was set to do the reduced form first.

$$\text{dss} = \underset{(0.000615)}{0.000343.} \tag{23}$$

11.6 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 β						
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 α						
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

Table 7: One-step ahead forecast statistics for period 2014.1−2015.4: series dss

Model	RMSE	mean(error)	SD(error)	min(error)	max(error)
M1	0.0023	-0.0016	0.0017	-0.0038	0.0008
M2	0.0022	-0.0016	0.0016	-0.0042	0.0008
AR	0.0053	-0.0010	0.0052	-0.0071	0.0107
RW	0.0054	-0.0009	0.0053	-0.0071	0.0108

Table 8: Forecast directional accuracy of alternative exchange rate models:
One-step ahead forecasts for period 2014.1−2015.4, series *dss*

	2014.1	2014.2	2014.3	2014.4	2015.1	2015.2	2015.3	2015.4	Matches
Actual	−	−	−	+	−	−	−	+	
M1	+	−	−	+	+	+	+	+	4/8
M2	+	−	−	+	+	+	+	+	4/8
AR	+	+	+	+	+	+	+	+	2/8
RW	+	+	+	+	+	+	+	+	2/8

Table 9: Forecast-encompassing test statistics for alternative exchange rate models:
One-step ahead forecasts for period 2014.1−2015.4, series dss

Encom-passing Model (h)	Null hypothesis	d.f.	M1	M2	AR	RW	Null hypothesis	d.f.	F-value
	F-values of pairwise forecast-encompassing test statistics (tail probabilities in parentheses)		Model to be encompassed (l)				Multiple-model ($\forall l \neq h$) forecast-encompassing test statistics (tail probabilities in parentheses)		
M1	$\kappa_l = 0; \kappa_0 \equiv 0$	1,7	0.00	0.00	2.49	6.15	$\forall \kappa_l = 0; \kappa_0 \equiv 0$	3,5	2.39
			(0.99)	(0.98)	(0.16)	(0.04)			(0.19)
	$\kappa_l = 0$	1,6		0.31	1.70	0.00	$\forall \kappa_l = 0$	3,4	0.39
				(0.60)	(0.24)	(1.00)			(0.77)
	$\kappa_l = \kappa_0 = 0$	2,6		2.92	4.23	2.63	$\forall \kappa_l = \kappa_0 = 0$	4,4	1.43
				(0.13)	(0.07)	(0.15)			(0.37)
M2	$\kappa_l = 0; \kappa_0 \equiv 0$	1,7	0.03	0.02	2.26	6.62	$\forall \kappa_l = 0; \kappa_0 \equiv 0$	3,5	3.41
			(0.88)	(0.88)	(0.18)	(0.04)			(0.11)
	$\kappa_l = 0$	1,6	0.11		3.31	0.00	$\forall \kappa_l = 0$	3,4	0.75
			(0.76)		(0.12)	(1.00)			(0.58)
	$\kappa_l = \kappa_0 = 0$	2,6	2.94		6.06	2.84	$\forall \kappa_l = \kappa_0 = 0$	4,4	2.05
			(0.13)		(0.04)	(0.14)			(0.25)
AR	$\kappa_l = 0; \kappa_0 \equiv 0$	1,7	22.2	23.6	0.00	0.26	$\forall \kappa_l = 0; \kappa_0 \equiv 0$	3,5	19.6
			(0.00)	(0.00)	(0.95)	(0.62)			(0.00)
	$\kappa_l = 0$	1,6	61.2	67.6		0.00	$\forall \kappa_l = 0$	3,4	15.1
			(0.00)	(0.00)		(1.00)			(0.01)
	$\kappa_l = \kappa_0 = 0$	2,6	31.9	35.2		0.11	$\forall \kappa_l = \kappa_0 = 0$	4,4	11.8
			(0.00)	(0.00)		(0.90)			(0.02)
RW	$\kappa_l = 0; \kappa_0 \equiv 0$	1,7	22.9	23.9	0.00	0.22	$\forall \kappa_l = 0; \kappa_0 \equiv 0$	3,5	10.1
			(0.00)	(0.00)	(1.00)	(0.65)			(0.02)
	$\kappa_l = 0$	1,6	57.5	60.4	1.55		$\forall \kappa_l = 0$	3,4	35.4
			(0.00)	(0.00)	(0.23)				(0.00)
	$\kappa_l = \kappa_0 = 0$	2,6	29.7	31.3	0.89		$\forall \kappa_l = \kappa_0 = 0$	4,4	27.4
			(0.00)	(0.00)	(0.46)				(0.00)

Table 10: Parameter encompassing test statistics

Test	Distribution	M1 v M2	p-value	Distribution	M2 v M1	p-value
Cox	N(0,1)	-1.512	0.131	N(0,1)	-3.685**	0.000
Ericsson IV	N(0,1)	1.341	0.180	N(0,1)	3.128**	0.002
Sargan	$\chi^2(7)$	29.89**	0.000	$\chi^2(7)$	32.36**	0.000
Joint Model	F(3,61)	0.851	0.472	F(3,61)	2.500	0.068

Figure 1: TT time series 1996.1-2015.4

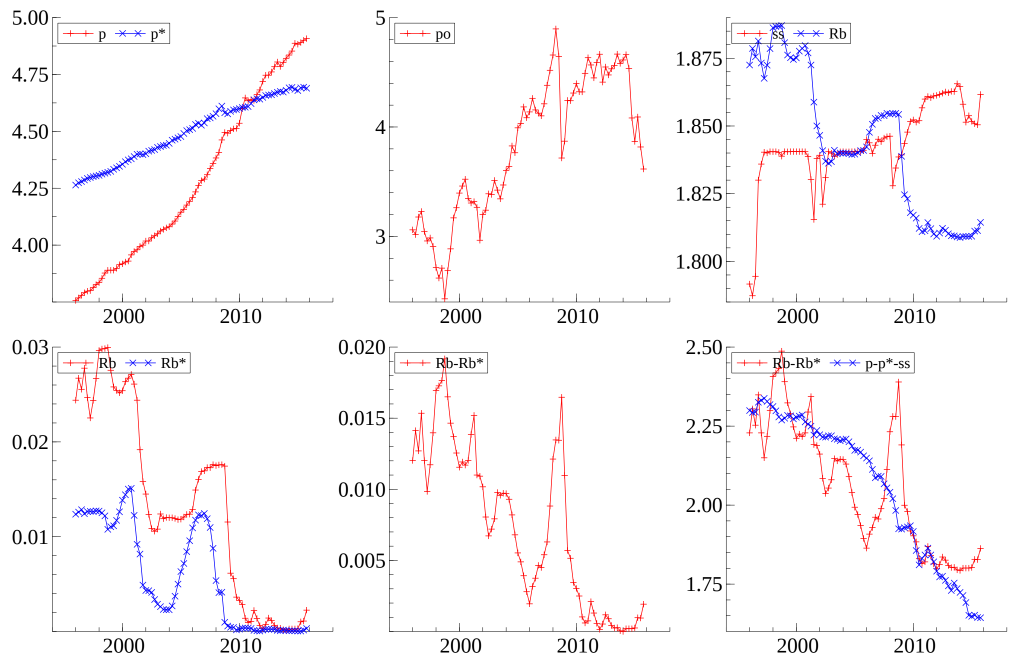


Figure 2: System graphical diagnostic statistics

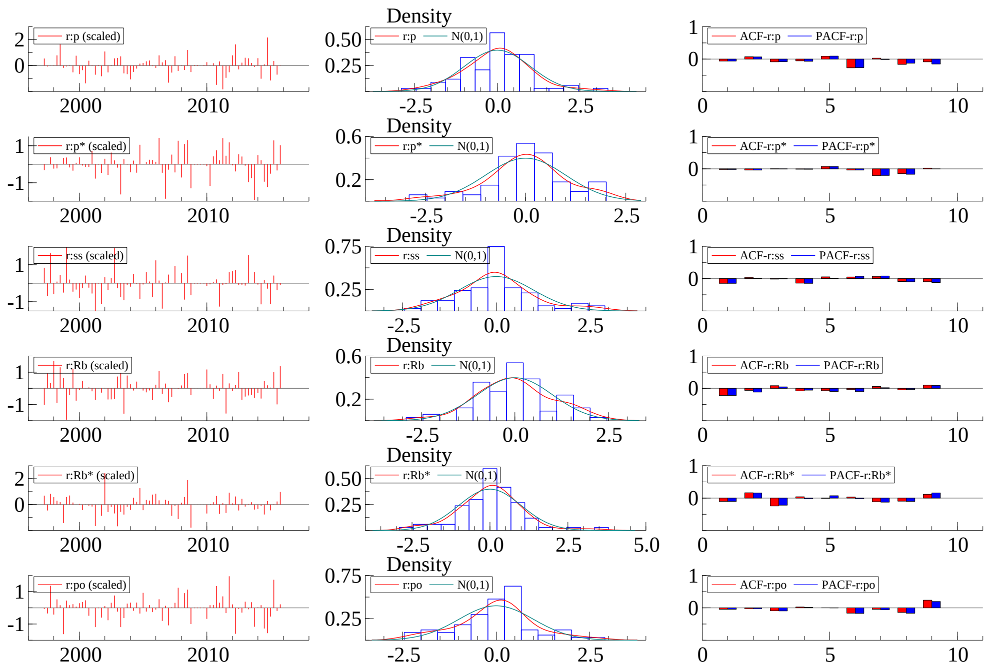


Figure 3: System graphical recursive statistics

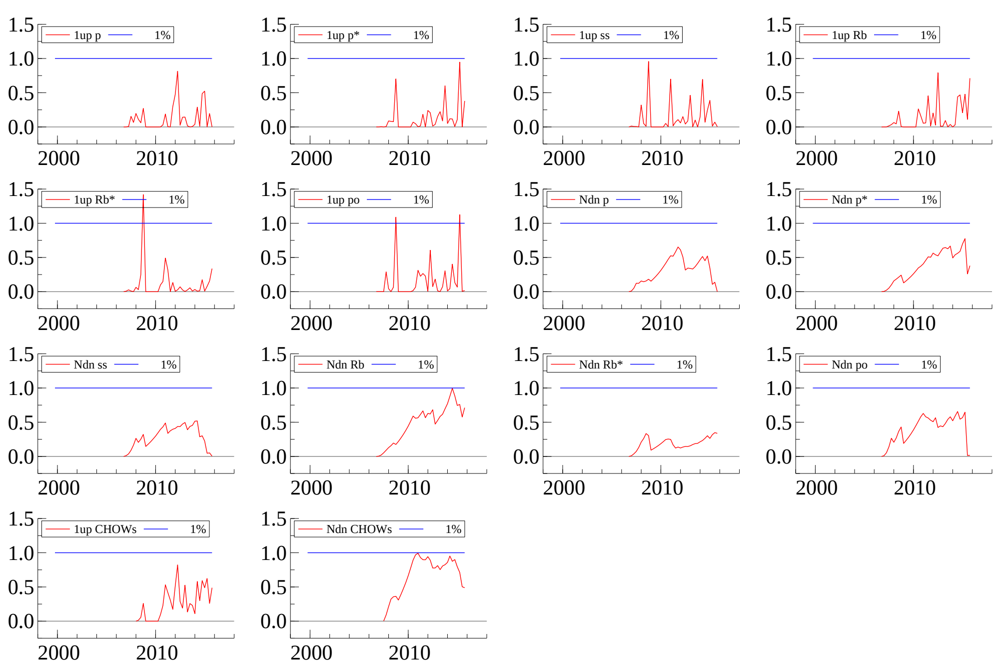


Figure 4: Recursive eigenvalues

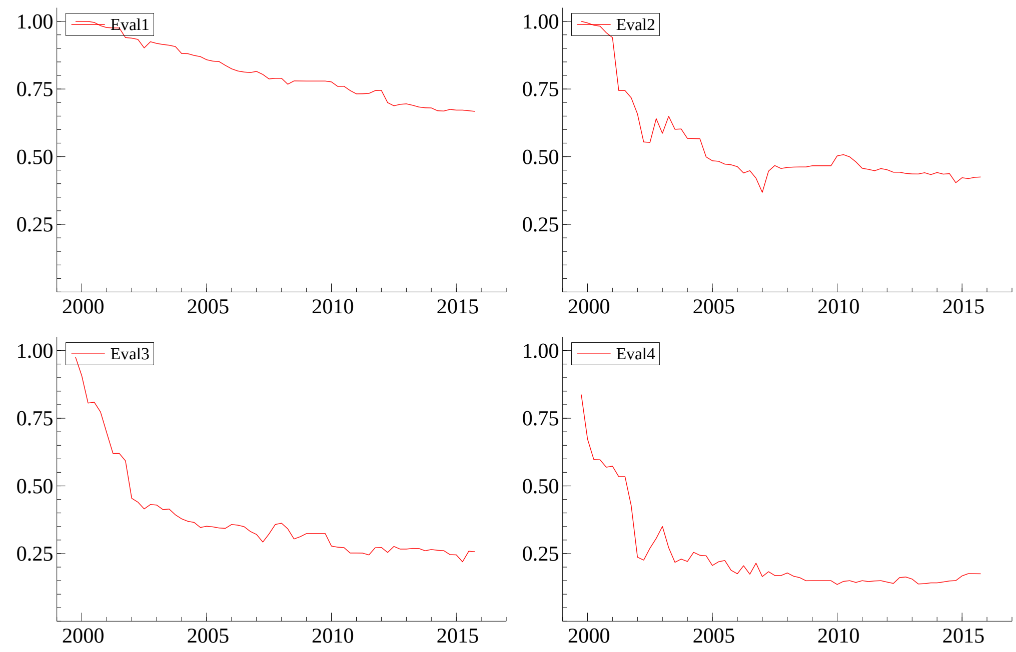


Figure 5: Unrestricted long-run relations, i.e. eigenvectors as defined in Table 2

Figure 6: Graphical regression information (Parsimonious VEqCM)

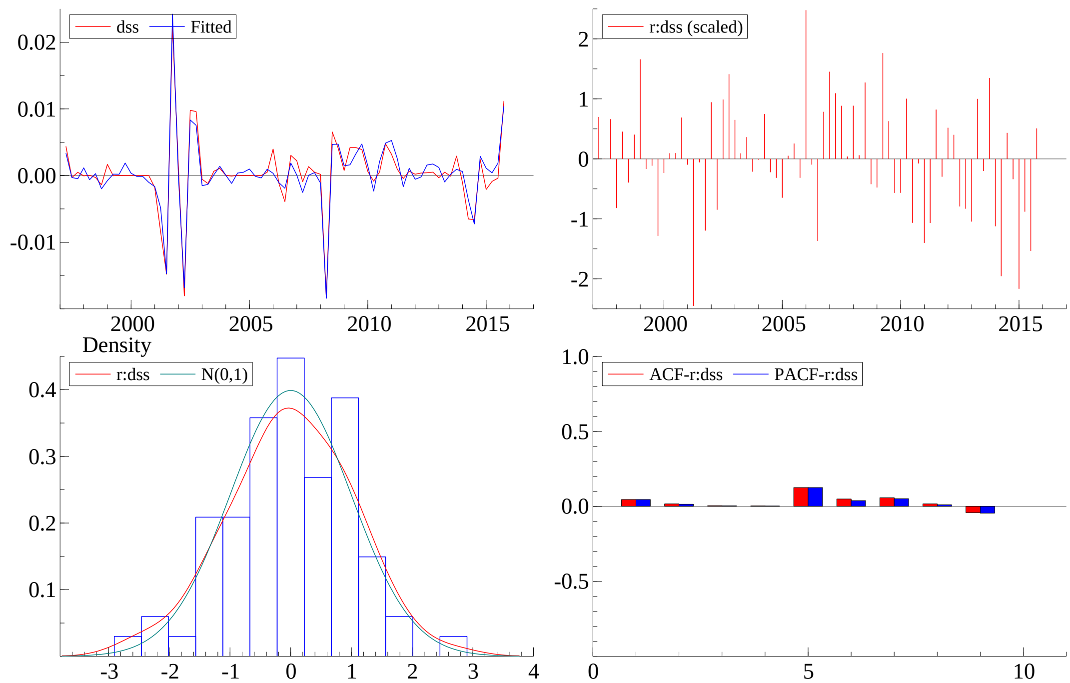


Figure 7: Recursive FIML statistics Δss (Parsimonious VEqCM)

Figure 8: Recursive OLS statistics Δss (Parsimonious VEqCM)

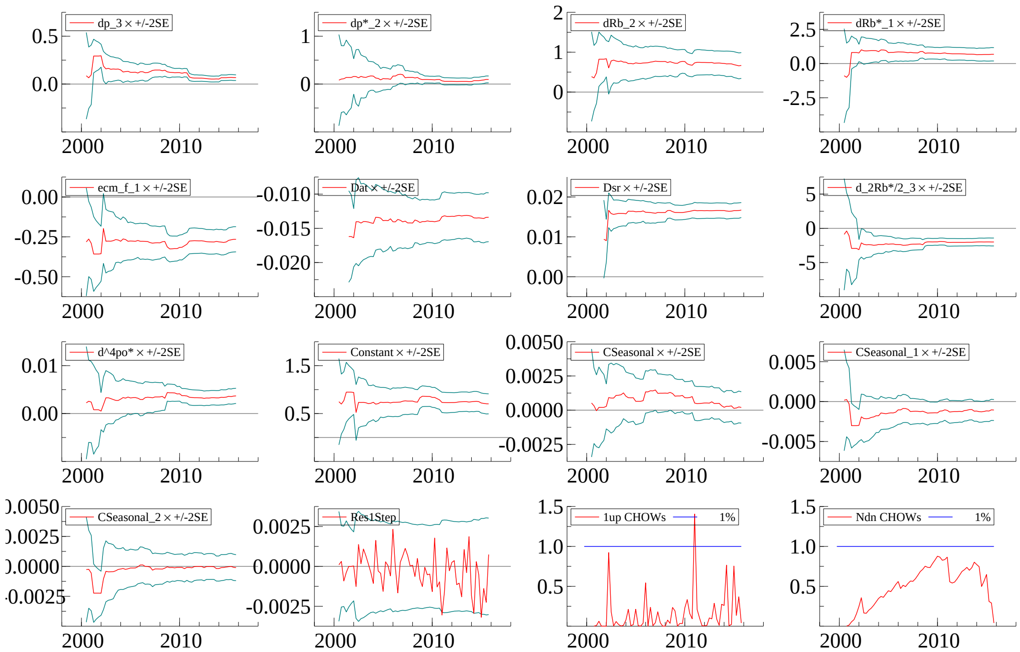


Figure 9: One-step residuals w/ $\pm\ 2\hat{\sigma}$ & Break-point Chows (p top row, p^* bottom row)

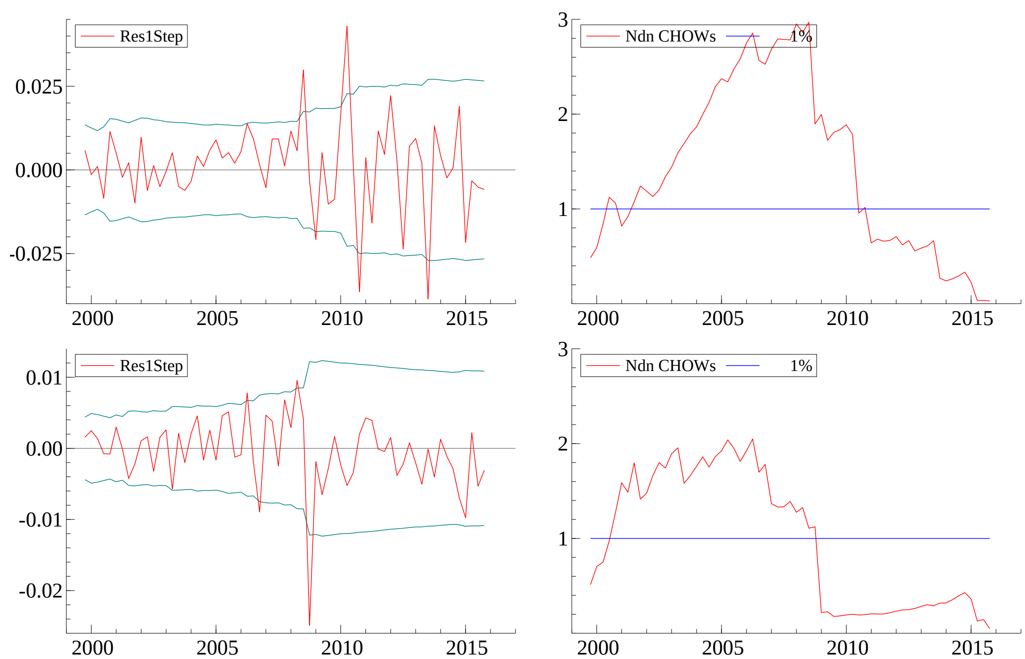


Figure 10: One-step residuals w/ $\pm\, 2\hat{\sigma}$ & Break-point Chows (Rb top row, Rb^{*} bottom row)

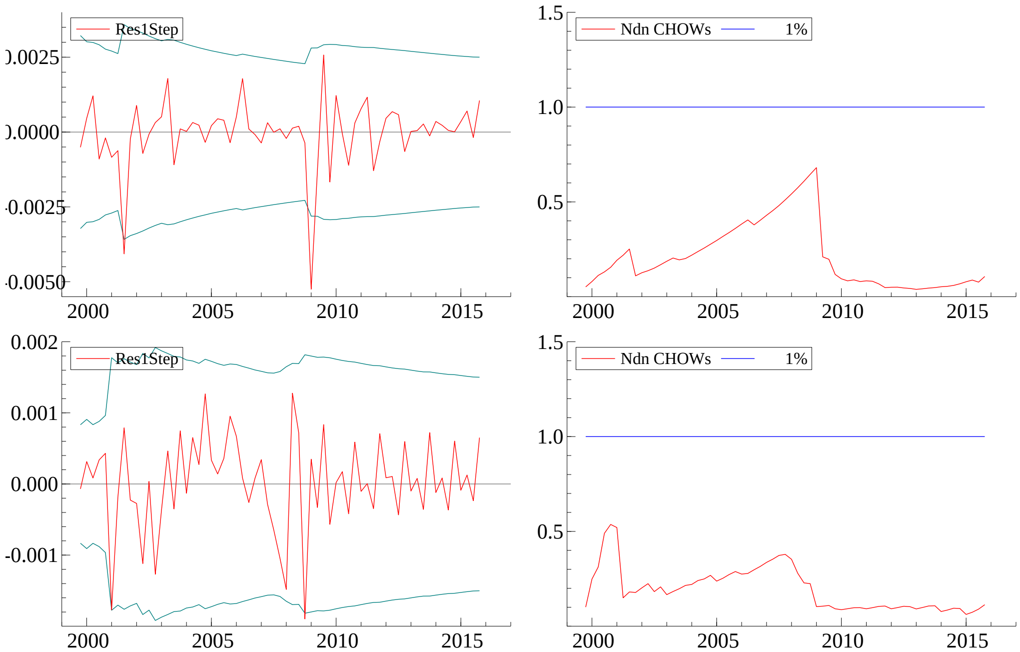


Figure 11: Forecasts in log first-differences for period 2014.1−2015.4

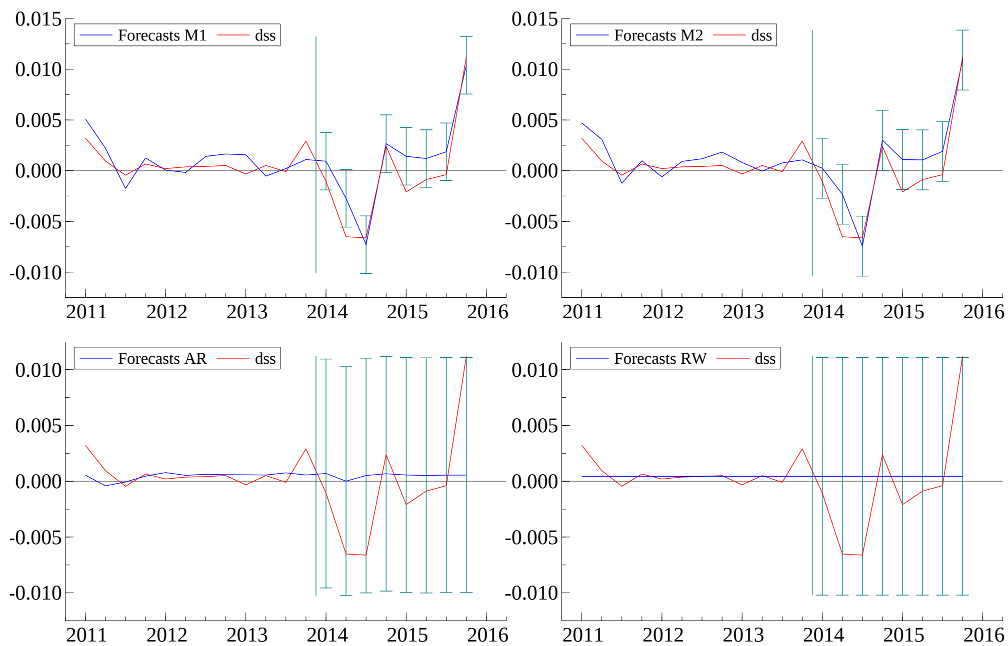
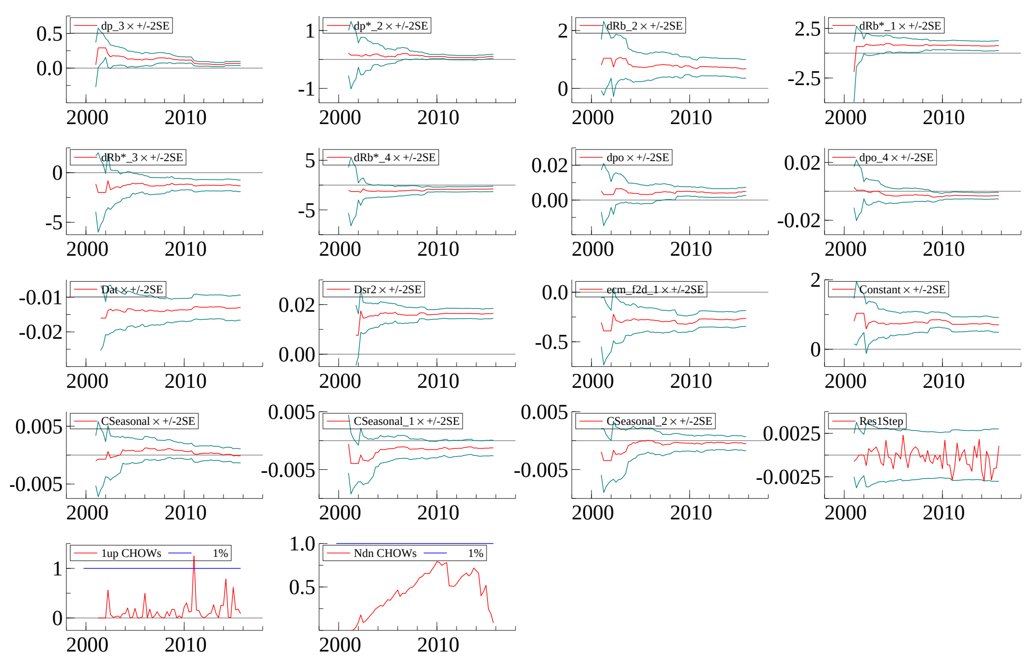


Figure 12: Forecasts in log-levels for period 2014.1−2015.4

Figure 13: Recursive OLS statistics Δss



11.7 Supplementary Appendix

This appendix presents the specification for VEqCM of model M2 developed in this paper prior to imposing non-zero parameter restrictions, as well as diagnostic and recursive graphics of both the VEqCM and parsimonious VEqCM.

$$
\begin{aligned}
\text{dss} \;=\; & \underset{(0.015)}{0.07}\ \text{dp}_{t-3} + \underset{(0.0314)}{0.142}\ \text{dp*}_{t-2} + \underset{(0.16)}{0.584}\ \text{dRb}_{t-2} \\
& + \underset{(0.209)}{0.602}\ \text{dRb*}_{t} - \underset{(0.265)}{1.11}\ \text{dRb*}_{t-3} - \underset{(0.259)}{0.817}\ \text{dRb*}_{t-4} \\
& - \underset{(0.00162)}{0.0148}\ \text{Dat}_{t} + \underset{(0.000961)}{0.0178}\ \text{Dsr}_{t} + \underset{(0.00101)}{0.00299}\ (\text{po-fpo})_{t} \\
& - \underset{(0.000941)}{0.00254}\ (\text{po-fpo})_{t-4} - \underset{(0.0386)}{0.268}\ \text{ecm}_{f\,t-1} + \underset{(0.103)}{0.711}
\end{aligned}
\tag{24}
$$

log-likelihood $= 385.429$ $\quad R^2 = 0.93$ $\quad \sigma = 0.0016$
$T = 75$ $\quad$ no. of parameters $= 12$ $\quad AR : F(5, 58) = 0.16[0.9746]$
$ARCH : F(4, 67) = 0.295[0.8799]$ $\quad Normality : \chi^2(2) = 1.25[0.5349]$
$HeteroA : F(20, 53) = 1.83[0.0409]*$ $\quad RESET : F(2, 61) = 0.86[0.4283]$

Figure 14: Graphical regression information for VEqCM M2.
Estimation sample is 2007.2−2015.4

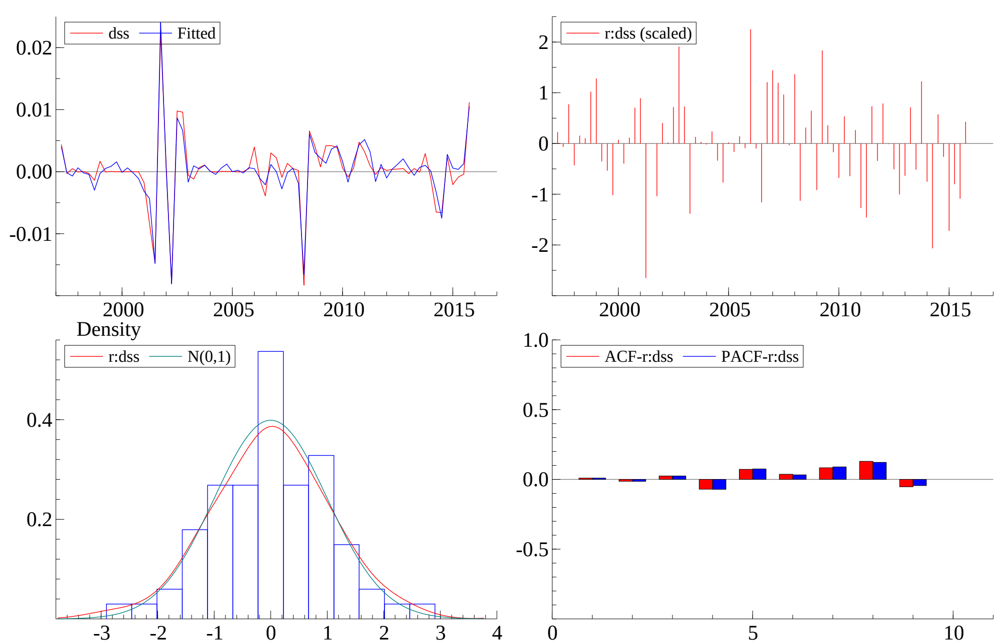


Figure 15: Recursive OLS statistics for VEqCM M2.
Estimation sample is 2007.2−2015.4

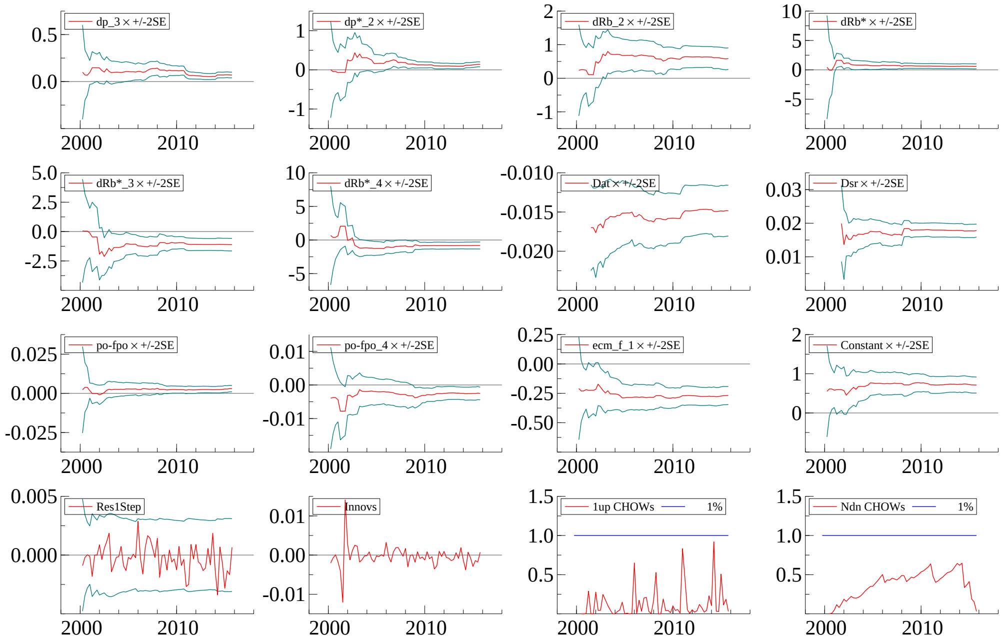


Figure 16: Graphical regression information for parsimonious VEqCM M2.
Estimation sample is 2007.2−2015.4

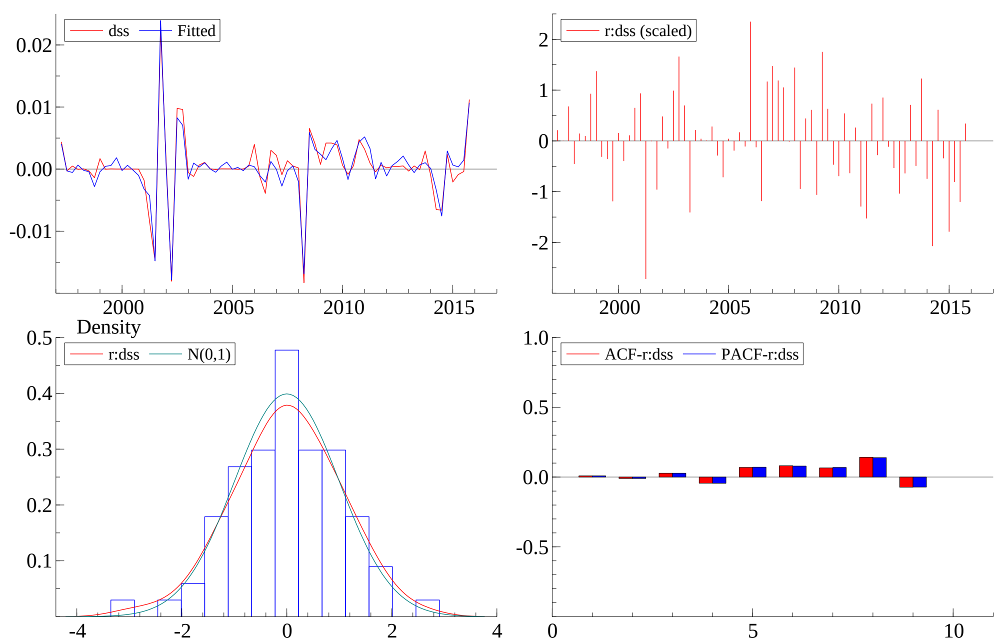


Figure 17: Recursive OLS statistics for parsimonious VEqCM M2.
Estimation sample is 2007.2−2015.4