NBER WORKING PAPER SERIES

HOARDING FOR STORMY DAYS - TEST OF INTERNATIONAL RESERVES PROVIDING FINANCIAL BUFFER SERVICES

Joshua Aizenman
Yothin Jinjarak

Working Paper 25909
http://www.nber.org/papers/w25909

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
May 2019, Revised March 2020

The financial support of the Dockson Chair research fund of University of Southern California is gratefully acknowledged. All data and reproduction codes are available upon request. Our data is mostly from Thomson Reuters (3rd party) and we have not posted our series on any URL. We gratefully acknowledge the useful comments of anonymous referees. The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research.

Hoarding for Stormy Days - Test of International Reserves Providing Financial Buffer Services
Joshua Aizenman and Yothin Jinjarak
NBER Working Paper No. 25909
May 2019, Revised March 2020
JEL No. F31,F34,F41

ABSTRACT

This paper outlines a tractable cost-benefit analysis of the buffer stock financial services provided by international reserves and applies it to 8 of the largest Emerging Markets (BRICS, Indonesia, Mexico, Turkey) during 2000-2019. The efficient management of international reserves generates sizable benefits for countries characterized by hard-currency external debt. These benefits increase with the volatility of the real exchange rates and sovereign spreads. While the first-best policy calls for prudential regulations, counter-cyclical management of hoarding reserves in good times and selling them in bad times provides buffers stock financial services adding up to about 3% of GDP during our sample period.

Joshua Aizenman
Economics and SIR
USC
University Park
Los Angeles, CA 90089-0043
and NBER
aizenman@usc.edu

Yothin Jinjarak
School of Economics and Finance
Victoria University of Wellington
PO Box 600
23 Lambton Quay, Wellington
New Zealand
yothin.jinjarak@vuw.ac.nz

1. Introduction

Successful buffer stock management of international reserves (henceforth IR) provides significant financial services. The availability of IR mitigates financial fragility associated with balance sheet exposure to maturing foreign debt, a role highlighted by Rodrik (2006), Aizenman and Lee (2007), and Jeanne and Rancière (2011). The more recent research provides refined mechanisms explaining the evolution of IR use. Bocola and Lorenzoni (2017) investigated the fiscal signaling role of IR in stabilizing exposure to multiple equilibria. Bianchi, Hatchondo, and Martinez (2018) focused on the intertemporal arbitrage managed by the central banks in countries where the private sector does not internalize the social costs of growing balance sheet exposure to hard currency debt, and the central bank provides optimal hedging of the exposure to roll-over risks. Alfaro and Kanczuk (2019) studied the impact of growing external local currency borrowing induced by the post-GFC low-interest rates, explaining the simultaneous issuance of domestic debt by emerging markets, while accumulating reserves that act as a hedge against external shocks.

Against this background, our paper describes empirically a tractable framework accounting for the intertemporal aspect of IR management, focusing on the transfer of purchasing power from times of relative plenty to stormy, leaner times. We decompose the opportunity costs of managing the stock of international reserves over time into two terms: a flow measure, corresponding to buying and selling international reserves, plus the carrying cost of the stock. This decomposition allows us to quantify the welfare costs and benefits of an active flow policy of hoarding international reserves in good times and selling IR in bad times.

Specifically, we consider an economy with a traded and non-traded sector, a balance sheet exposure of hard currency debt, and a volatile real exchange rate. As noted by Rodrik (2006), the net effect of short-term borrowing matched by a dollar increase of reserves is that the economy has borrowed short term abroad, while accumulating a lower-yielding asset. In these circumstances, the sovereign spread between the private sector cost of short-term borrowing abroad and the yield on international reserves measures the opportunity cost of reserves in terms of foreign currency. This opportunity cost is measured in terms of the domestic purchasing power, obtained by multiplying the dollar opportunity cost with the real exchange rate (i.e., the local currency cost of a dollar deflated by the domestic price level). Conversely, the marginal benefit associated with selling one reserve dollar is the sovereign spread times the real exchange rate. It follows that international reserve accumulation, though itself costly, is in practice a store of tax revenue denominated in hard currency, to be used in bad times to serve external hard currency debt, while the domestic debt may be less costly to serve via inflation tax, financial repression, and other means [Aizenman and Marion (2004)].

Section 2 presents data and preliminary analysis using Russia as a case study, together with evidence from other emerging markets (BRICS, Indonesia, Mexico, Turkey). Section 3 follows with a comparative analysis of the eight emerging-market countries and supplements with two counterfactual-analysis studies of China and Russia. Section 4 provides concluding remarks.

2. Flow and stock IR management policies – definitions and measurement with a case study of Russia

We provide supporting evidence that bad times are associated with greater use of the international reserves to serve external debt. The government is concerned with the cost of sovereign debts, recognizing the impact of systemically important borrowers (i.e., large banks, state, and prime borrowers). Our analysis studies the benefits of IR buffer stock management in the context of the volatile real exchange rate, where the sovereign spreads may be affected by hoarding international reserves.

Focusing first on Russia, we start by illustrating the cumulative benefits of an active buffer stock policy for a prime commodity-exporting country. Our data include international reserves, nominal exchange rates, real exchange rates, sovereign bond yields, external debt, imports, and the monetary base. We use quarterly data from 2000Q1 to 2019Q1, extracted via the Eikon API from Thomson Reuters database of statistical reports of national agencies and international financial organizations. Appendix Figure A1 provides the time profile of macroeconomic series in our sample. For a commodity country, stronger terms of trade, higher dollar prices of oil in the case of Russia, go hands-in-hands with rising foreign-currency oil revenue, appreciating Ruble, and falling sovereign credit spreads, while the reverse applies at times of weaker terms of trade. This finding is in line with Algieri (2013), showing that the Russian real exchange rate determination depends on the fluctuation of oil prices and IR management. Qian and Steiner (2017) show that effective IR management increases the share of long-term in total external debt and reinforces financial stability. Bhattacharya, Mann, and Nkusu (2019) confirm empirically the importance of terms of trade volatility in accounting for the demand of IR by emerging markets economies.

2.1 The net present value of financial buffer stock services

The starting point of our analysis is Rodrik's (2006) public finance evaluation of the opportunity costs of international reserves (IR) in terms of sovereign spreads. Specifically, the spread between the yield on liquid reserve assets and the external cost of funds—a difference of several percentage points in normal times—represents the social cost of self-insurance. To illustrate, consider the case where Russian IR are held in the dollar, Russia's sovereign borrowing cost at time t is $i_{RU,t}$, and the interest rate on U.S. Treasury of the same maturity is i_t^*. Denoting Russian dollar international reserves at time t by $IR_{RU,t}$, the flow costs of Russian IR is the spread times the stock of international reserves, $IR_{RU,t}(i_{RU,t} - i_t^*)$.

Denoting the ruble cost of a dollar at time t by $E_{RU,t}$, Russian CPI at time t by $CPI_{RU,t}$, and the social discount factor by ρ, the net present value (n.p.v.) of Russian's IR opportunity cost held between the period t_1 and t_2, denoted by $\Gamma(IR_{RU;t_1 \dots t_2})$, is:

(1) $$\Gamma(IR_{RU;t_1 \dots t_2}) = -\sum_{t_1}^{t_2}[\frac{1}{(1+\rho)^t} IR_{RU,t}(i_{RU,t} - i_t^*)\frac{E_{RU,t}}{CPI_{RU,t}}]$$

The minus sign stands for cost, and the net present valuation is done in terms of Russian purchasing power discounted to time t_1. The opportunity cost is proportionate to the sovereign spreads during the period, weighted by the reserves evaluated in domestic purchasing power.

To gain further insight into the degree to which international reserves provide an efficient country cyclical buffer, we transform $\Gamma(IR_{RU;t_1 \dots t_2})$ into the sum of two terms: the NPV of the opportunity cost of the stock (cumulative), IR, and the NPV of the opportunity cost of the flow adjustments, $\Delta IR_{RU,t}$:

(1') $$\Gamma(IR_{RU;t_1 \dots t_2}) = -\sum_{t_1}^{t_2}[\frac{1}{(1+\rho)^t}(IR_{RU,t-1} + \Delta IR_{RU,t})(i_{RU,t} - i_t^*)\frac{E_{RU,t}}{CPI_{RU,t}}]$$

$$= -\sum_{t_1}^{t_2}[\frac{1}{(1+\rho)^t} IR_{RU,t-1}(i_{RU,t} - i_t^*)\frac{E_{RU,t}}{CPI_{RU,t}}] + \sum_{t_1}^{t_2}[\frac{1}{(1+\rho)^t}\phi(IR_{RU,t})]$$, where

(2) $$\phi(IR_{RU,t}) = -\Delta IR_{RU,t}(i_{RU,t} - i_t^*)\frac{E_{RU,t}}{CPI_{RU,t}} \quad ,$$

where $\Delta IR_{RU,t} = IR_{RU,t} - IR_{RU,t-1}$ stands for the hoarding of reserves at time t (depleting of reserves if negative). [1]

While the first term of (1'), $-\sum_{t_1}^{t_2}[\frac{1}{(1+\rho)^t} IR_{RU,t-1}(i_{RU,t} - i_t^*)\frac{E_{RU,t}}{CPI_{RU,t}}]$ is trivially negative, the second term, $\sum_{t_1}^{t_2}[\frac{1}{(1+\rho)^t}\phi(IR_{RU,t})]$, tends to be positive and higher if the central bank buys IR when their real prices are low, and sells IR when their real price is high. This will be the case if the Central bank buys IR when the rubble is strong (i.e., when $\frac{E_{RU,t}}{CPI_{RU,t}}$ is low), and sell the rubble is weak (when $\frac{E_{RU,t}}{CPI_{RU,t}}$) is high).

Henceforth, we denote the second term by $\Phi(IR_{RU;t_1,\dots,t_2})$;

(3) $$\Phi(IR_{RU;t_1,\dots,t_2}) = -\sum_{t_1}^{t_2}[\frac{1}{(1+\rho)^t}\Delta IR_{RU,t}(i_{RU,t} - i_t^*)\frac{E_{RU,t}}{CPI_{RU,t}}] = \sum_{t_1}^{t_2}[\frac{1}{(1+\rho)^t}\phi(IR_{RU,t})\frac{E_{RU,t}}{CPI_{RU,t}}]$$

The value of Φ measures Central Bank's countercyclical efficiency of trading IR. The benefits associated with Central Bank's foreign exchange "leaning against the wind" policy are higher if the bank buys IR in times of plenty (i.e., high oil price, low sovereign spreads, and strong Ruble), and sells IR in rainy days (i.e., low oil price, high sovereign spreads, and weak Ruble). The cumulated gain reported in (3) depends also on the volatility of the sovereign spreads, and the volatility of the real exchange rate during the sample period. Other things being equal, higher $\Phi(IR_{RU;t_1,\dots,t_2})$ is associated with a higher quality of IR management of a central bank during a commodity cycle. In the empirical applications of these equations, we recognize that countries hold their IR in a basket that includes the dollar as well as other currencies. As we do not have information on the varying currency composition for each country, we assume that their basket equals the average composition reported by the IMF. Specifically, we evaluate the international reserves by the sovereign spread on key currencies (US dollar, Euro, Japanese Yen, British pound) using the weights provide by the IMF for the 'average country' (see Appendix Figure A2 for the time profile of international interest rates, including US, Euro, Japan, and the UK). The weights applied to foreign interest rates and exchange rates are based on the currency composition of IR, shown in Appendix Figure A3.

Our estimates of IR financial buffer stock services may misstate both the real opportunity cost when purchasing IR in good times and the amount of benefit when selling IR in stormy days. According to the theory of precautionary IR, hoarding adequate IR reduces the likelihood of external debt crises and a bad equilibrium in the presence of balance sheet exposure; that is, country risk is lower when a country hoards adequate IR. Lower country risk leads to lower sovereign spread, hence lower real opportunity cost calculated according to equation (2). Thus, equation (2) understates the true real opportunity cost of hoarding IR. Moreover, selling IR to defend against the financial crisis makes the adverse impact of crisis less severe. Had a country got no IR to defend itself, the sovereign spread would be higher, and the exchange rate would depreciate further during a financial crisis, both of which bias down the social benefits provided by IR buffer stock role calculated by equation (2). Section 3 address this potential bias in detail.

2.2. An application for Russia and emerging markets: BRICS+3

Subject to the availability of quarterly data, the estimation sample starts as follows: Brazil: 2006Q1, China: 2002Q2, India: 2002Q1, Indonesia: 2003Q2, Mexico: 2003Q1, Russia: 2001Q3, Turkey: 2000Q2, South Africa: 2000Q2. We report in Figure 1 the cumulated buffer services of IR ($\Phi(IR_{RU,t})$) and the n.p.v. buffer services of IR ($\Gamma(IR_{RU,t})$) scaled by the average IR holdings ($M(IR_{RU,t})$), where a discount factor ρ is a 2 percent real interest rate. The top panel reports the cumulated social benefit of IR interventions, where buying reserves is a cost; selling is a benefit (equation (3): $\Phi(IR_{RU,t})$ on the left axis; $\frac{\Phi(IR_{RU,t})}{M(IR_{RU,t}))}$ on the right axis). The bottom panel reports the time path of the n.p.v. of social costs of the stock of reserves (equation (1): $\Gamma(IR_{RU,t})$ on the left axis; $\frac{\Gamma(IR_{RU,t})}{M(IR_{RU,t}))}$ on the right axis). For the case of Russia, Figure 1.1 top panel indicates that during 2002-2019, the Russian central bank interventions added to the benefit of about

2 percent of the average IR (discounted to 2002), shifting purchasing power from good times (when Russia hoarded IR) to bad times (when Russia sold IR to service and pay some of its terms debt). Figure 1.1 bottom panel indicates that the total cost for Russia during that period was about 5 percent of its average IR position.

For cross-country comparison, we report the flow buffer services of IR ($\phi(IR_{LCU,t})$) scaled by GDP ($YR_{LCU,t}$); LCU denotes the local currency unit adjusted by the weighted real exchange rates (equation (2)). Figure 2.1 illustrates the case study of Russia; Figures 2.2-2.8 provide the measures for other emerging markets in the BRICS+3 group. The top panel plots the flow costs and benefits of IR buffer services of Russia from 2001 to 2019, defined by equation (2) ($\phi(IR_{RU,t})$, dotted line, left axis), and the flow costs and benefits scaled by Russia's real GDP ($\frac{\phi(IR_{RU,t})}{YR_{RU,t}}$, solid line, right axis). The middle panel traces the real exchange rate ($\frac{E_{RU,t}}{CPI_{RU,t}}$, solid line, left axis in log scale; higher values correspond to a weaker Russia's real exchange rate), and the sovereign credit spreads ($i_{RU,t} - i_t^*$, dotted line, right axis). The bottom panel provides the quarterly percentage change of IR ($\Delta IR_{RU,t}$, dotted line, left axis), and the oil price (USD/barrel, solid line, right axis).

The price of oil increased in the early 2000s from about 30 USD/barrel to 140 USD/barrel before the global financial crisis. During that period, the Ruble appreciated, and the Central Bank of the Russian Federation increased its international reserves rapidly, reaching more than 600 billion USD. The flow (opportunity) cost of this IR accumulation, traced in the top panel of Figure 2.1, was well below 1/3 percent of the GDP during most of this period. In contrast, during the worst part of the Global Financial Crisis when the Ruble was sharply depreciating, and Russia's sovereign credit spreads were rapidly increasing, the central bank sold more than 200 billion USD of Russia's IR, providing the Russian economy significant flow benefits of hoarding IR close to 1.5 percent of the GDP. Similar patterns applied from the early 2010s, a time of renewed rising oil prices, until the sharp drop in 2015. These charts show a remarkable coherence of the Russian intervention with the logic of buffer management – selling IR at times of rising sovereign spreads, funding thereby the reduction of foreign-currency external debt by IR that the central bank accumulated in times of plenty (i.e., rising oil prices, appreciating ruble, and declining sovereign spreads).

To put this discussion in the proper perspective, note that the overall successful buffer policy of Russia during 2000-2019 is a second-best policy. The first-best policy may include macroprudential regulations and possibly external-borrowing taxes to scale down the balance sheet exposure of Russia by raising the costs of borrowing in good times. Proper application of these policies may reduce the need for large hoarding to support the bailouts of systemic borrowers in bad times (Rodrik (2006)). Such a first-best policy also reduces the exposure to the moral hazard associated with bailing out borrowers in bad times. Political economy considerations suggest that the Russian central bank, operating with limited ability to impose macroprudential regulations on powerful insiders, may be credited for saving Russia from a much costlier exposure to sudden stops of the 1998 Russian crisis variety.[2]

3. Comparative Analysis

For our comparative analysis, we test the association between IR financial buffer stock services and its components for Russia and Mexico, having sufficiently long data series covering two decades. We use the vector autoregression (VAR) methodology to estimate the impact of reserve accumulation, sovereign spreads, and real exchange rates on the IR financial buffer services during the period from 2000 to 2019. Notably, the feedback among our key variables violates the assumption of exogeneity. For example, currency appreciation and declining sovereign spreads may encourage reserve accumulation. A favorable history of IR financial buffer services may lower over time spreads and may induce more hoarding of reserves. The VAR methodology may deal with some of these concerns by tracing the responses of IR financial buffer services to its components and the responses of its components to IR financial buffer services.

Specifically, we consider the following system of equations for IR financial buffer stock services (fbs), the real exchange rate (rer), sovereign spreads (spr), and IR hoarding (irh):

(4) $$fbs_t = \alpha_{10} + A_{11}(L)fbs_{t-1} + A_{12}(L)rer_{t-1} + A_{13}(L)spr_{t-1} + A_{14}(L)irh_{t-1} + e_{1t}$$

$$rer_t = \alpha_{20} + A_{21}(L)fbs_{t-1} + A_{22}(L)rer_{t-1} + A_{23}(L)spr_{t-1} + A_{24}(L)irh_{t-1} + e_{2t}$$

$$spr_t = \alpha_{30} + A_{31}(L)fbs_{t-1} + A_{32}(L)rer_{t-1} + A_{33}(L)spr_{t-1} + A_{34}(L)irh_{t-1} + e_{3t}$$

$$irh_t = \alpha_{40} + A_{41}(L)fbs_{t-1} + A_{42}(L)rer_{t-1} + A_{43}(L)spr_{t-1} + A_{44}(L)irh_{t-1} + e_{4t}$$

where $fbs_t = \frac{\phi(IR_{RU,t})}{YR_{RU,t}}, irh_t = \Delta IR_{RU,t}, spr_t = i_{RU,t} - i_t^*, rer_t = \frac{E_{RU,t}}{CPI_{RU,t}}, \alpha_{i0} =$ the vectors containing constants; $A_{ij}(L) =$ the polynomials in the lag operator L; $e_{ij} =$ i.i.d. disturbance terms. Augmented Dickey-Fuller tests reject the null hypothesis that these series have unit roots (non-stationary). Since we used quarterly data, we include a maximum of 4 lags. Using AIC criteria to select the optimal number of lags, we found that 1 lag was appropriate in this sample.

To assess the interactions between the series, we obtained the variance decompositions. The moving-average representations of the above system of equations express $fbs_t, irh_t, spr_t, rer_t$ as dependent on the current and past values of $e_{1t}, e_{2t}, e_{3t}, e_{4t}$ sequences:

(5) $$fbs_t = a_0 + \sum_{j=1}^{T}[\,(a_{1j}e_{1t-j} + a_{2j}e_{2t-j} + a_{3j}e_{3t-j} + a_{4j}e_{4t-j})] + e_{1t}$$

$$rer_t = b_0 + \sum_{j=1}^{T}[\,(b_{1j}e_{1t-j} + b_{2j}e_{2t-j} + b_{3j}e_{3t-j} + b_{4j}e_{4t-j})] + e_{2t}$$

$$spr_t = c_0 + \sum_{j=1}^{T}[\,(c_{1j}e_{1t-j} + c_{2j}e_{2t-j} + c_{3j}e_{3t-j} + c_{4j}e_{4t-j})] + e_{3t}$$

$$irh_t = d_0 + \sum_{j=1}^{T}[\,(d_{1j}e_{1t-j} + d_{2j}e_{2t-j} + d_{3j}e_{3t-j} + d_{4j}e_{4t-j})] + e_{4t}$$

where a_0, b_0, c_0, d_0 are vectors containing constants; and $a_{.j}, b_{.j}, c_{.j}, d_{.j}$ are parameters. We use the residuals of VAR estimation and then decomposed the variances of $fbs_t, irc_t, spr_t, rer_t$ into percentages attributable to each type of innovation. We apply the orthogonalized innovations obtained from a Choleski decomposition; the order of the variables in the factorization had qualitative effects on the results, depending on the contemporaneous correlations among $e_{1t}, e_{2t}, e_{3t}, e_{4t}$.

The variance decompositions for an 8-quarter forecasting horizon are in Table 1. Each time series explains most of its past values; fbs_t explains over 95.4 percent of its forecast error variances, spr_t 59.2 percent, rer_t 42.2 percent, and irh_t 28.9 percent. Notably, IR buffer stock services (fbs_t) explain 38.8 percent for Russia's sovereign spread (spr_t), 32.4 percent of the forecast error variance of Russia's real exchange rate (rer_t), and 66.5 percent for Russia's IR hoarding (irh_t). Note, however, that the contemporaneous correlation among $e_{1t}, e_{2t}, e_{3t}, e_{4t}$ were about 0.5 across the pairs of residuals.

To support the order of the variables in the factorization above, shown in Table 2, we apply Granger causality tests. We find that the effects of IR hoarding on IR buffer stock services are significant at the 0.0965 level, and the effects of real exchange rate on IR buffer stock services are significant at the 0.0137 level. In contrast, the effects of IR buffer stock services on the real exchange rate and IR hoarding are not statistically significant at conventional 0.1000 levels. For Russia, our tests, therefore, suggest that causality goes from IR hoarding to real exchange rate, sovereign spread, and IR buffer stock services. Thus, causality is unidirectional. Note, however, that the causality tests for IR buffer stock services to GDP are more conclusive than the tests for IR buffer stock services to M2; more on the normalization by M2 and internal drainage of IR below). Overall, this finding helps address the concern that an endogeneity in equations (1) – (3) might cause a misestimation in the IR buffer stock services.

3.1 Benefits of IR buffer stock services and dependence on commodity exports

Do interactions of IR buffer stock services, real exchange rates, sovereign spreads, and IR hoarding vary with country dependence on commodity exports? Considering the size of commodity exports/GDP and commodities/exports (UNCTAD), Brazil, Indonesia, Russia, and South Africa stand out as commodity exporters in this sample. The share of commodities in total exports is Brazil 63%, Indonesia 58%, Russia

74%, South Africa 55%, compared to China 8%, India 42% (of which 37% was refined petroleum of mostly imported crude oil), Mexico 19%, and Turkey 23%. We estimated the variance decomposition for Russia and Mexico, as both have a sufficiently long time series for the tests. Figure 3 summarizes the findings. Despite the much lower commodity exposure of Mexico relative to Russia, they share similar variance decomposition - IR buffer stock services explain more than 60 percent of the forecast error variance in IR hoarding of Russia and Mexico.

De facto exchange rate management is probably relevant to these findings. According to the IMF classification, except China, all other countries in our sample are under a floating exchange rate regime. Referring to the Granger causality tests in Table 2.1, the effects Russia's IR hoarding on the real exchange rate is significant at the 0.0667 level, while the effects of Russia's real exchange rate on IR buffer stock services and sovereign spreads are significant at the 0.0137 and 0.0234, respectively. For Russia, the tests suggest a unidirectional causality. In contrast, the direction of causality is inconclusive in the case of Mexico. These findings portray a different picture of the financial benefits of IR buffer stock services for commodity and non-commodity exporters. Our measure of IR buffer stock services captures mostly the precautionary motives for the commodity exporters, while other motives (e.g., mercantilist) are confounders in the IR hoarding of non-commodity exporters and might contribute to underestimation of the IR buffer stock services. These country-specific differences highlight the benefits of combining our framework with a country case study and policy attributes.

We also use OLS estimation to examine the associations. Tables 3.1-3.3 account for the importance of the reserve accumulation, sovereign spreads and real exchanges in explaining the time variation of the total net present value of the costs of the IR over time per dollar reserves. The results indicates the following patterns in our sample:

IR flow services (percent of GDP): On average, countries with the largest flow benefits are Brazil, followed by India, and Turkey. Real exchange rate (E/CPI) explains more than half of the IR flow services.

IR cumulated flow services (percent of IR): On average, countries with the largest cumulated benefits are Turkey, followed by Indonesia, and South Africa. Real exchange rate (E/CPI) and sovereign spreads explain most of the IR cumulated services.

IR cumulated flow services + opportunity costs (percent of IR): On average, countries with the largest cumulated benefits are Turkey, followed by Indonesia, and South Africa. Real exchange rate (E/CPI) and sovereign spreads explain most of the IR cumulated services. Note that IR opportunity costs are much greater than the cumulated flow services.

Commodity exporters and reserve-hoarding benefits:

The financial services of reserve hoarding also vary with country dependence on commodity exports. Table 4 reports the coefficient estimates of real exchange rates across our measures of buffer-stocks IR services along with commodity exports/GDP and commodities/exports. Brazil, Indonesia, Russia, and South Africa evidently stand out as commodity exporters in this sample.

For the group of commodity exporters, the coefficient estimates of real exchange rate (E/CPI) for Russia are largely supportive that the real depreciation increases the IR financial services. For Brazil, Indonesia, and South Africa, we find the opposite: the coefficient estimates of real exchange rate are negative, suggesting that the real depreciation lowers the IR services; the results for Brazil are mixed, depending on our IR service measures.

For the group of non-commodity exporters, our estimates for China and India consistently show that real exchange rate depreciation increases the IR financial services. We do not find such supportive evidence for Mexico and Turkey.

3.2 Internal and external drainage of IR

Thus far, we measured IR buffer stock services relative to GDP. Obstfeld et al. (2010) pointed out that the internal drain (e.g., capital flight from domestic M2) is an important factor affecting the holding of IR in developing countries. If part of IR is used to deal with the flight of M2, $i_{RU;t}$ in equation (1) and other equations is replaced by the weighted average, $w_{xd} * i_{RU;t}^{ext} + w_{M2} * i_{RU;t}^{int}$, where w_{xd} and w_{M2} are, respectively, the relative weight that IR is used for insurance against external debt crisis and internal drain of M2 (i.e., bank run); $i_{RU;t}^{ext}$ is the interest rate of hard currency liabilities and $i_{RU;t}^{int}$ is the interest rate of domestic currency liabilities.

Considering that we do not have adequate disaggregated interest rate data on both the hard currency and domestic currency liabilities for countries in the sample, we added in Table 2 the variance decomposition of IR buffer stock services relative to M2 in Figure 3, and the corresponding Granger causality tests. The effects of Russia's IR hoarding on the real exchange rate is significant at the 0.0667 level, while the effects of Russia's real exchange rate on IR buffer stock services and sovereign spreads are significant at the 0.0003 and 0.0234, respectively. While our findings are consistent across the denominators (i.e., GDP, M2), more analysis on the external and internal drainage of IR deserves further investigation and is left for future research. Future extensions may also integrate the concepts of international reserves and foreign currency liquidity as outlined in IMF (2013), highlighting the distinction across foreign currency resources (IR and other foreign currency assets) and foreign currency drains (predetermined foreign currency liabilities and financial derivative positions, and contingent drains from undrawn credit lines).

3.3 IR hoarding and the counterfactuals

Our measure of the cost and benefit of IR hoarding hinges on the real exchange rate and sovereign spread. However, if the spread is fair compensation for default risk, and in the absence of frictions associated with costly enforcement of contracts and other frictions, we may consider it not a cost. In a model with excess returns, Bianchi et al. (AER 2018) show that optimal IR policy is determined also by the effect of IR on spreads. In addition to the variance decomposition of IR hoarding, sovereign spread, and real exchange rate presented above, Figure 4 and Table 5 provide a counterfactual analysis of the size of China's reserves and real exchange rates. China's reserves accumulation accelerated from less than 20 percent of GDP in the 2000s, reached almost 50 percent of GDP in early 2010 and had since decelerated. The counterfactual analysis focused on the causal effect of this IR policy intervention on a time series of China's real exchange rate. Given the China's real exchange rate (henceforth RER) time series and a set of control RER time series (Brazil, India, Indonesia, Mexico, Russian, Turkey, and South Africa), we follow Brodersen et al. (2015), constructing a Bayesian structural time-series model to predict the counterfactual, i.e., how China's RER would have evolved after the 2010 China's IR intervention if the intervention had never occurred.

As the counterfactual analysis is a non-experimental approach to causal inference, the assumption is that there is a set control time series (RER of other EMs) that were themselves not affected by China's IR intervention. If the RER of Brazil and other EMs were affected by China's IR policy of 2010, this analysis might misestimate the true effect. The counterfactual analysis also assumes that the relationship between China's RER (treated) and other EMs' RER (controlled) time series during the pre-treatment period is stable throughout the post-treatment period. Subject to specific priors, the analysis performs posterior inference on the counterfactual and returns a China's counterfactual RER. To estimate a causal effect, we used the observations of 2002Q2-2009Q4 for training the model (pre-intervention period) and the observations of the 2010Q1-2019Q1 period for computing a counterfactual prediction (post-intervention period). We then examined China's real exchange rate series and counterfactuals based on the Bayesian structural time-series models, comparing the actual data and a counterfactual prediction for the post-treatment period. We also estimated the difference between observed China's RER data and counterfactual China's RER predictions; the pointwise causal effect, as estimated by the model. The counterfactual prediction suggested that the deceleration of reserve hoarding policy resulted in the appreciation of the Chinese real exchange rate close to 20 percent in the decade that followed. This evidence was supportive that China's IR intervention had a causal effect on China's RER. Because our controls (other EMs' RER series) might be affected by China's intervention, the analysis depended on whether this assumption is justified.

4. Concluding Remarks

Our analysis focused on the recent international reserves management of emerging-market economies. The sample period covers 2000-2019, including the commodity cycles of 2002-2007, and the oil-price rise and the drop of 2014, events that significantly impacted terms of trade of emerging markets. We provided a tractable analysis of the costs and benefits of the precautionary management of reserves, aiming at reducing the expected costs of serving external debt at times of volatile commodity terms of trade and heightened real exchange rate volatility. The exposure to commodity cycles is not unique to the emerging markets, yet emerging markets tend with limited financial development tend to rely more on active international reserves management.[3]

Issues left future study include the rollover risks and liquidity needs of financial institutions, the availability of swap lines among the central banks, active hedging of commodity risk via options by central banks, prudential regulations and active management of assets and liabilities aiming at reducing mismatches in maturity, interest rate, foreign exchange risks, and optimal exchange rate policy.

References

Aizenman, Joshua, and Marion, Nancy, 2004, International Reserve Holdings with Sovereign Risk and Costly Tax Collection, *Economic Journal*, 114, 569-591.

Aizenman, Joshua, and Lee Jaewoo, 2007, International reserves: precautionary versus mercantilist views, theory and evidence." *Open Economies Review* 18.2 (2007): 191-214.

Alfaro, Laura, and Kanczuk, Fabio, 2019, Debt Redemption and Reserve Accumulation, *IMF Economic Review*, 67, 2, 261-287.

Bhattacharya, Rina, Katja Mann, and Mwanza Nkusu, 2019, Estimating the demand for reserve assets across diverse groups of countries, *Review of International Economics*, 27:822–853.

Bocola, Luigi, and Lorenzoni, Guido, 2017, Financial Crises, Dollarization, and Lending of Last Resort in Open Economy.

Bianchi, Javier, Hatchondo, Juan Carlos, and Martinez, Leonardo, 2018, International Reserves and Rollover Risk, *American Economic Review*, 108, 9, 2629-2670.

Brodersen KH, Gallusser F, Koehler J, Remy N, Scott SL., 2015, Inferring causal impact using Bayesian structural time-series models. *Annals of Applied Statistics*, 9, 1, 247-274.

Dominguez, Kathryn M.E., Hashimoto, Yuko, and Ito, Takatoshi, 2012, International Reserves and the Global Financial Crisis, *Journal of International Economics*, 88, 388-406.

International Monetary Fund, 2013, International reserves and foreign currency liquidity: guidelines for a data template, Washington, D.C.

Olivier Jeanne, and Rancière, Romain, 2011, The Optimal Level of International Reserves for Emerging Market Countries: A New Formula and Some Applications, *Economic Journal*, 121, 555, 905–930

Meyer, Josefin, Reinhart, Carmen M., and Trebesch, Christoph, 2019, Sovereign Bonds since Waterloo, NBER WP # 25543.

Obstfeld, Maurice, Shambaugh, Jay C., and Taylor, Alan M., 2010, Financial Stability, the Trilemma, and International Reserves, *American Economic Journal: Macroeconomics*, 2, 57-94.

Qian, Xingwang, and Andreas Steiner, 2017, International reserves and the maturity of external debt, *Journal of International Money and Finance*, 73, 399-418.

Rodrik, Dani, 2006, The Social Cost of Foreign Exchange Reserves, *International Economic Journal*, 20, 3, 253-266.

Endnotes:

1. With quarterly data, a more proper way may be multiplying $-\Delta IR_{RU,t}$ by the average value of $(i_{RU,t} - i_t^*) \frac{E_{RU,t}}{CPI_{RU,t}}$ at the beginning and the end of each quarter, $\left[\frac{E_{RU,t}}{CPI_{RU,t}}(i_{RU,t} - i_t^*) + \frac{E_{RU,t-1}}{CPI_{RU,t-1}}(i_{RU,t-1} - i_{t-1}^*)\right] * 0.5$. The gap between this average and the way that we do it is of secondary importance for ϕ (defined by equation 2) and Φ (defined by equation (3).
2. Examining data from 1815-2017 covering 88 countries, Meyer, Reinhart, and Trebesch (2019) find an average excess return of external sovereign bonds above US government bonds is 4 about percent, concluding that overtime, sovereign bonds charge high enough interest to compensate for volatile sovereign risk, frequently outperforming corporate bonds and stocks. These results suggest that the optimal management of external sovereign borrowing depends on the horizon of policy-makers, the quality of institutions, and the enforcement of regulations.
3. Advanced economies such as Canada went through a period of high public debt and exchange rate interventions aiming at stabilizing the exchange rate, notably during 1995-1998. Canada has since been not active in the foreign exchange intervention, and its recent reserve management is mostly for precautionary purposes, aiming at minimizing the damage associated with foreign exchange market breakdowns, and the prospect of extreme foreign exchange movements that may induce financial instability.

Data, Figures, Tables

International Reserves

We collected data on international reserves (IR) in US dollars (current prices, not seasonally adjusted) from Thomson Reuters and calculated quarterly IR hoarding (ΔIR). Assuming that the process of IR accumulation is uniformly distributed throughout a quarter.

Currency composition of IR

The world currency composition of foreign exchange reserves from the IMF COFER data. A limitation is that the unallocated reserves account for approximately fifty percent of total IR data.

Nominal exchange rates

The end-of-quarter nominal exchange rates (E), defined by local currency per US dollar, from Thomson Reuters, and calculated nominal depreciation against the US dollar.

Consumer Price Indexes

Consumer price indices (CPI) were the year 2010 based and not seasonally adjusted, extracted from Thomson Reuters.

Real Exchange Rates

The real exchange rates as ($\frac{E}{CPI}$) and real effective exchange rate series ($REER$) from the BIS website.

Sovereign Spreads

We estimated sovereign spreads ($i - i^*$; 1-year and 10-year) as follows. First, we collected quarterly US, Euro, Japan, and UK interest rates from Thomson Reuters. Then, using quarterly weights from the world currency composition of foreign exchange reserves, we calculated the weighted foreign interest rates from a basket of US, Euro, Japan, and UK interest rates.

GDP

The quarterly nominal GDP in local currency and real GDP growth (year on year) from Thomson Reuters.

External Debt

The sovereign external debt in US dollars from Thomson Reuters.

M2

The broad monetary base M2 from Thomson Reuters.

Imports and Exports

Data on imports and exports are in US dollars, from Thomson Reuters, UNCTAD, and the World Bank.

Commodity Prices

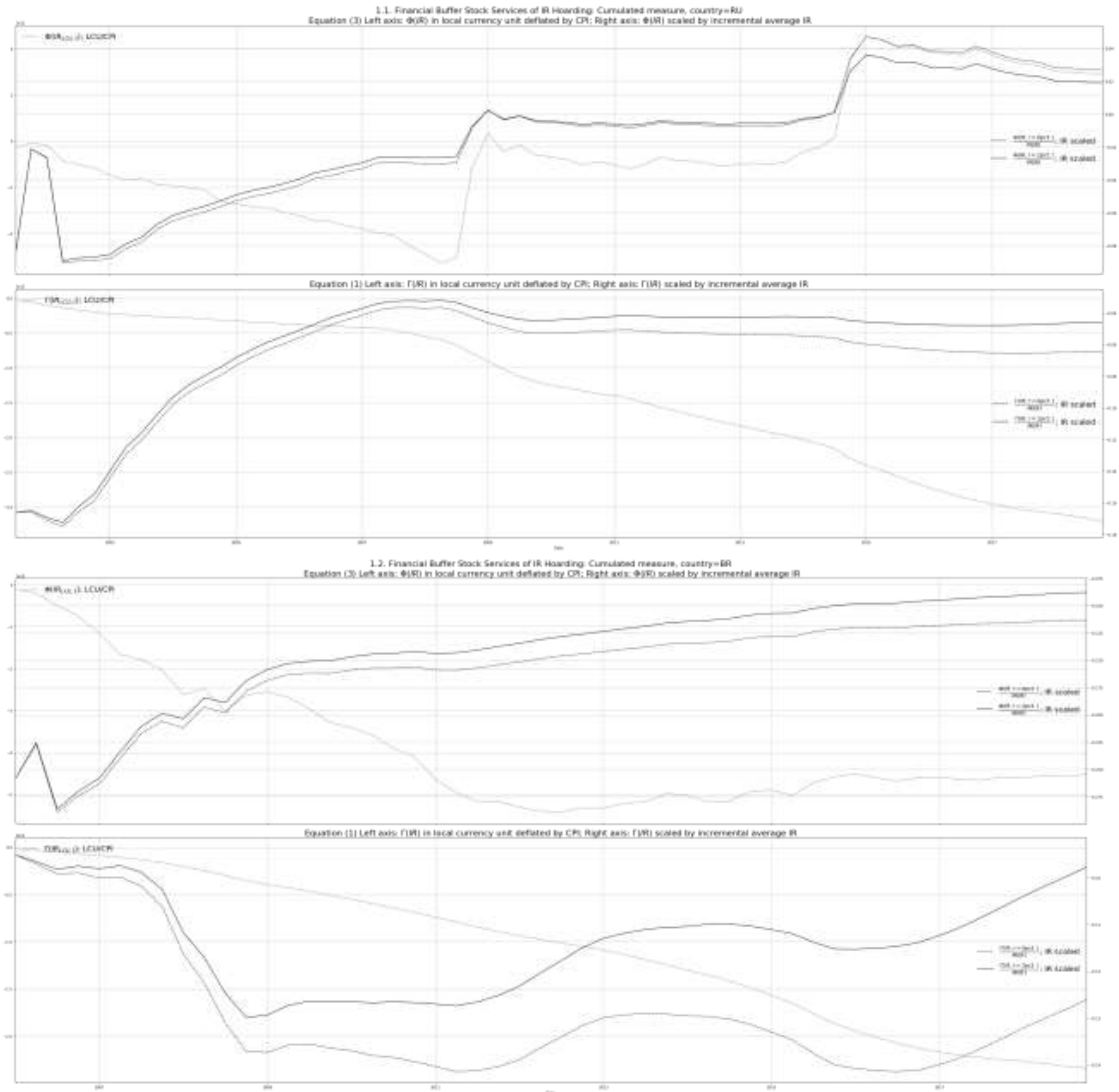
We use oil price data and terms of trade series from Thomson Reuters.

Sample periods

Subject to the availability of quarterly data, countries have different start years of observations. Specifically, Brazil: 2006Q1; China: 2002Q2; India: 2002Q1; Indonesia: 2003Q2; Mexico: 2003Q1; Russia: 2001Q3; Turkey: 2005Q1; South Africa: 2013Q3. Our sample ends 2019Q2.

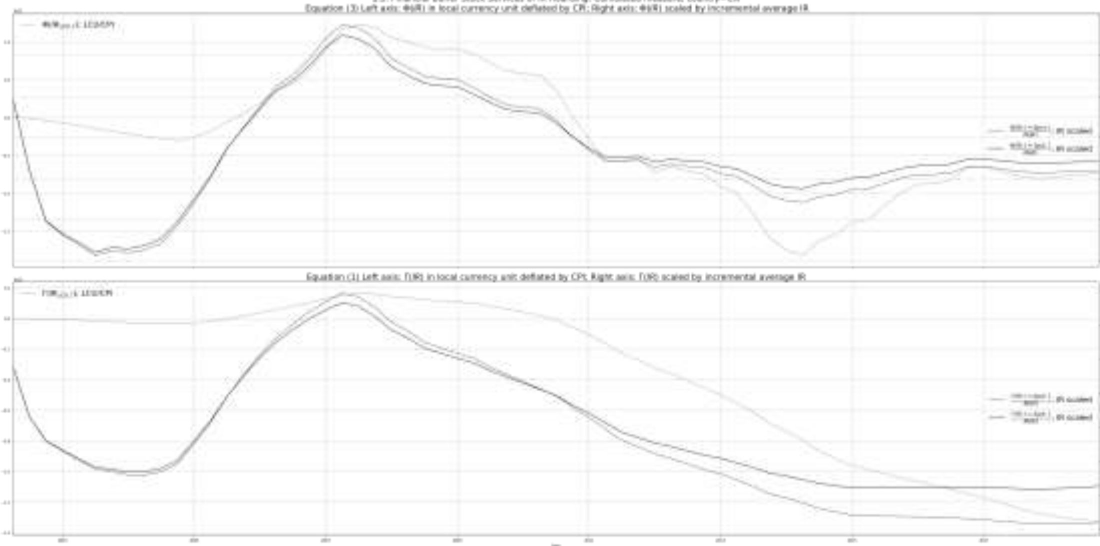
Figure 1. Financial Buffer Stock Services of IR Hoarding: Stock (cumulative) measure

Based on equation (3), the top panel left scale in the dotted .. curve is $\Phi(IR)$ in real LCU (deflated by CPI, where CPI at the year 2010 was 100), n.p.v. discounted at the 2 percent rate to the sample start. The top panel right scale in the solid (dashed) curve is $\Phi(IR)$ in terms of the (incremental) average international reserves n.p.v. discounted at the 2 (0) percent rate to the sample start; 0.03 is 3 percent of the discounted IR in the corresponding year. Based on equation (1), the bottom panel left scale in the dotted .. curve is $\Gamma(IR)$ in real LCU (deflated by CPI, where CPI at the year 2010 was 100), n.p.v. discounted at the 2 percent rate to the sample start. The bottom panel right scale is $\Gamma(IR)$ in terms of the (incremental) average international reserves ($M(IR)$) from the sample start to that specific year/quarter; 0.05 is 5 percent of the discounted IR in the corresponding year. The solid (dash) curve corresponds to n.p.v. discounted at the rate of 2 (0) percent to the sample start. The estimation uses sovereign spreads over weighted average global rates (USD, GBP, JPY, EUR). Reserve accumulation: $100 * [IR_t - IR_{t-1}]/IR_{t-1}$. Source: Thomson Reuters Eikon API.



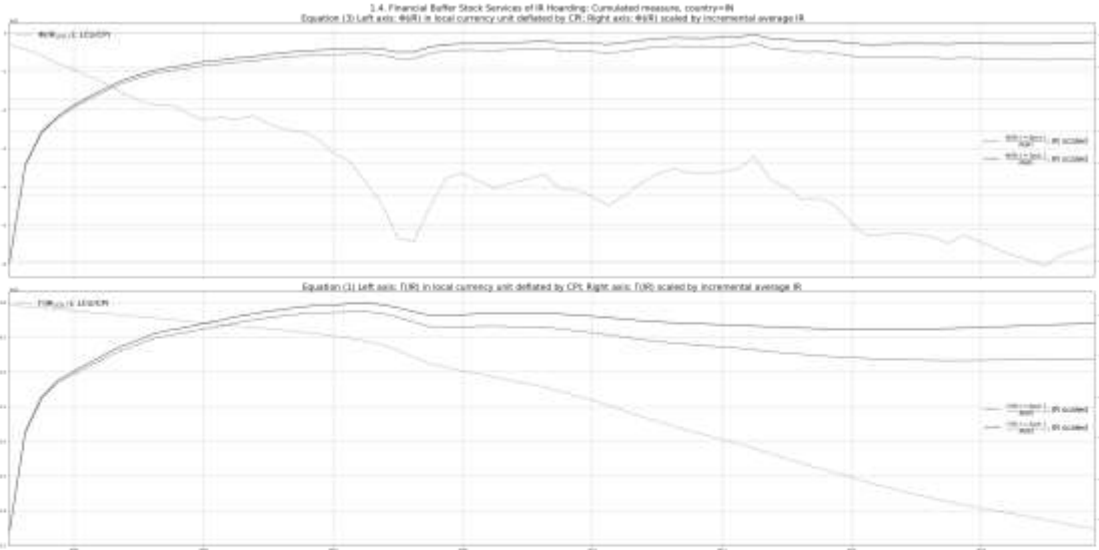
1.3. Financial Buffer Stock Services of IR Hoarding: Cumulated measure, country=CN

Equation (3) Left axis: Φ(IR) in local currency unit deflated by CPI; Right axis: Φ(IR) scaled by incremental average IR



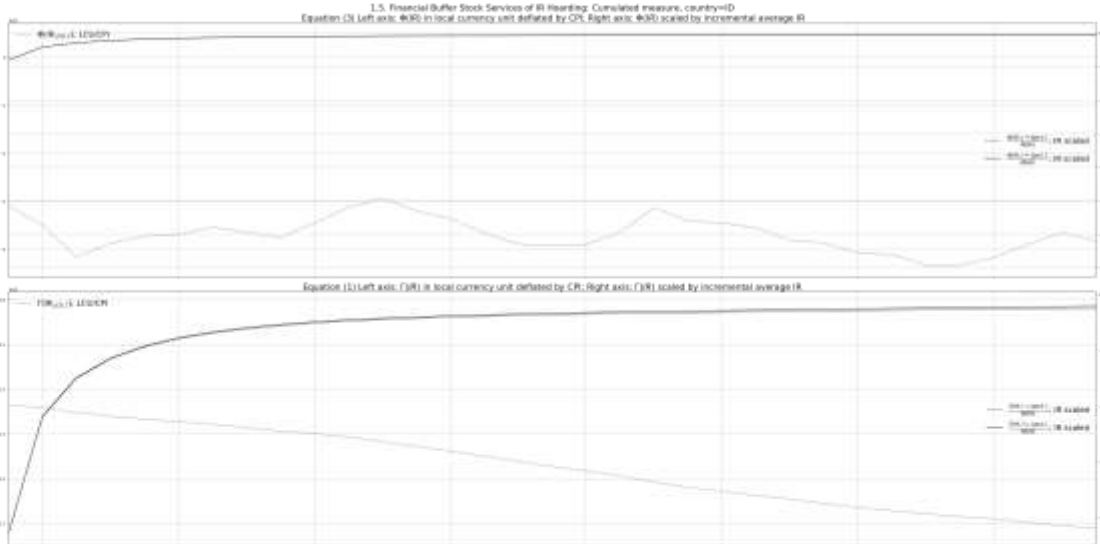
1.4. Financial Buffer Stock Services of IR Hoarding: Cumulated measure, country=IN

Equation (3) Left axis: Φ(IR) in local currency unit deflated by CPI; Right axis: Φ(IR) scaled by incremental average IR

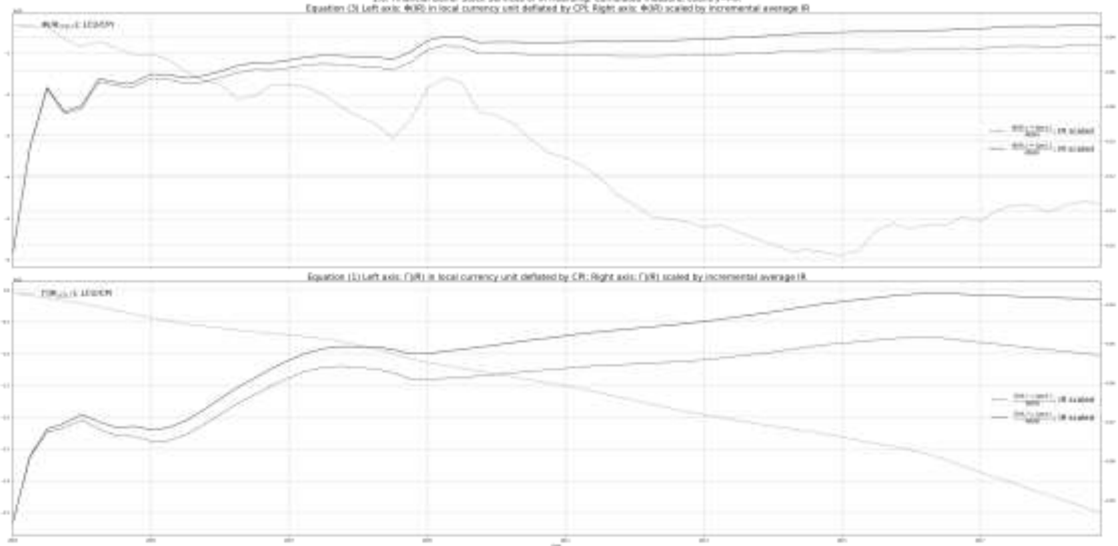


1.5. Financial Buffer Stock Services of IR Hoarding: Cumulated measure, country=ID

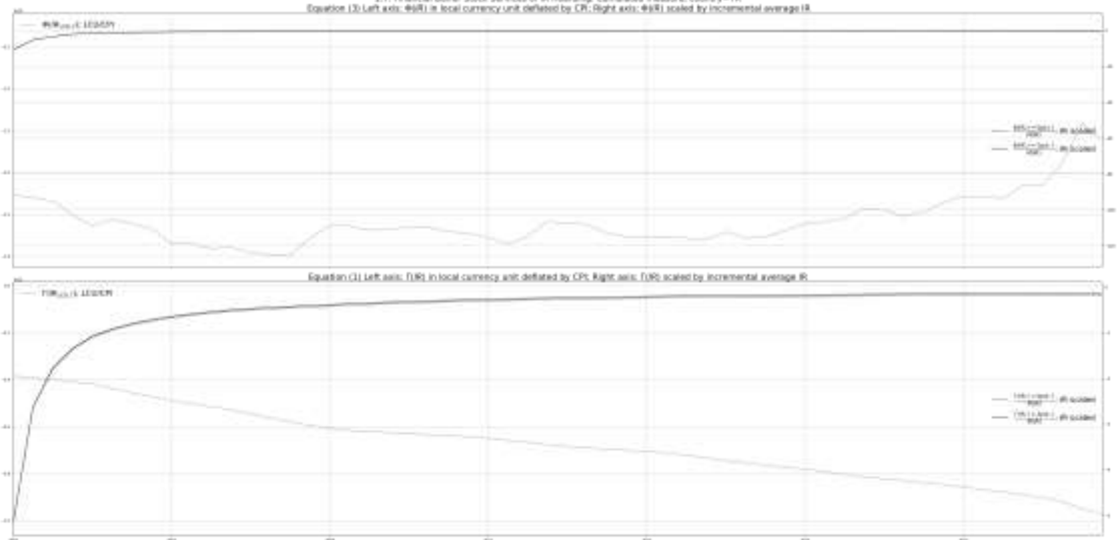
Equation (3) Left axis: Φ(IR) in local currency unit deflated by CPI; Right axis: Φ(IR) scaled by incremental average IR



1.6. Financial Buffer Stock Services of IR Hoarding: Cumulated measure, country=MX
Equation (3) Left axis: Φ(IR) in local currency unit deflated by CPI; Right axis: Φ(IR) scaled by incremental average IR



1.7. Financial Buffer Stock Services of IR Hoarding: Cumulated measure, country=TR
Equation (3) Left axis: Φ(IR) in local currency unit deflated by CPI; Right axis: Φ(IR) scaled by incremental average IR



1.8. Financial Buffer Stock Services of IR Hoarding: Cumulated measure, country=ZA
Equation (3) Left axis: Φ(IR) in local currency unit deflated by CPI; Right axis: Φ(IR) scaled by incremental average IR

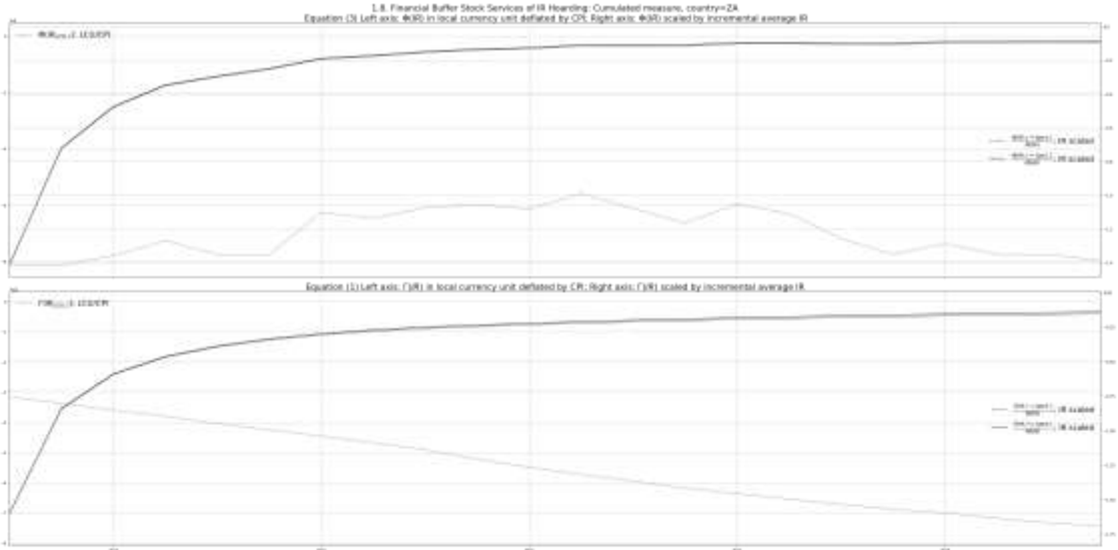
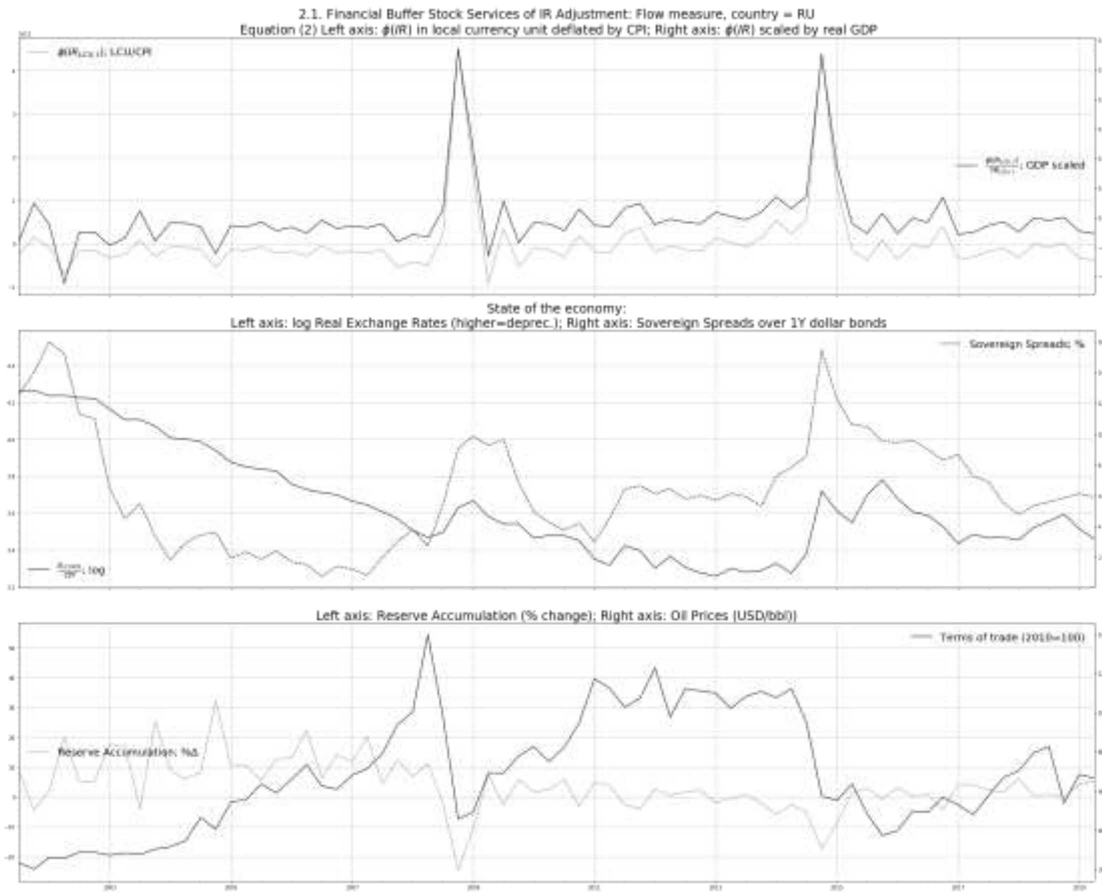
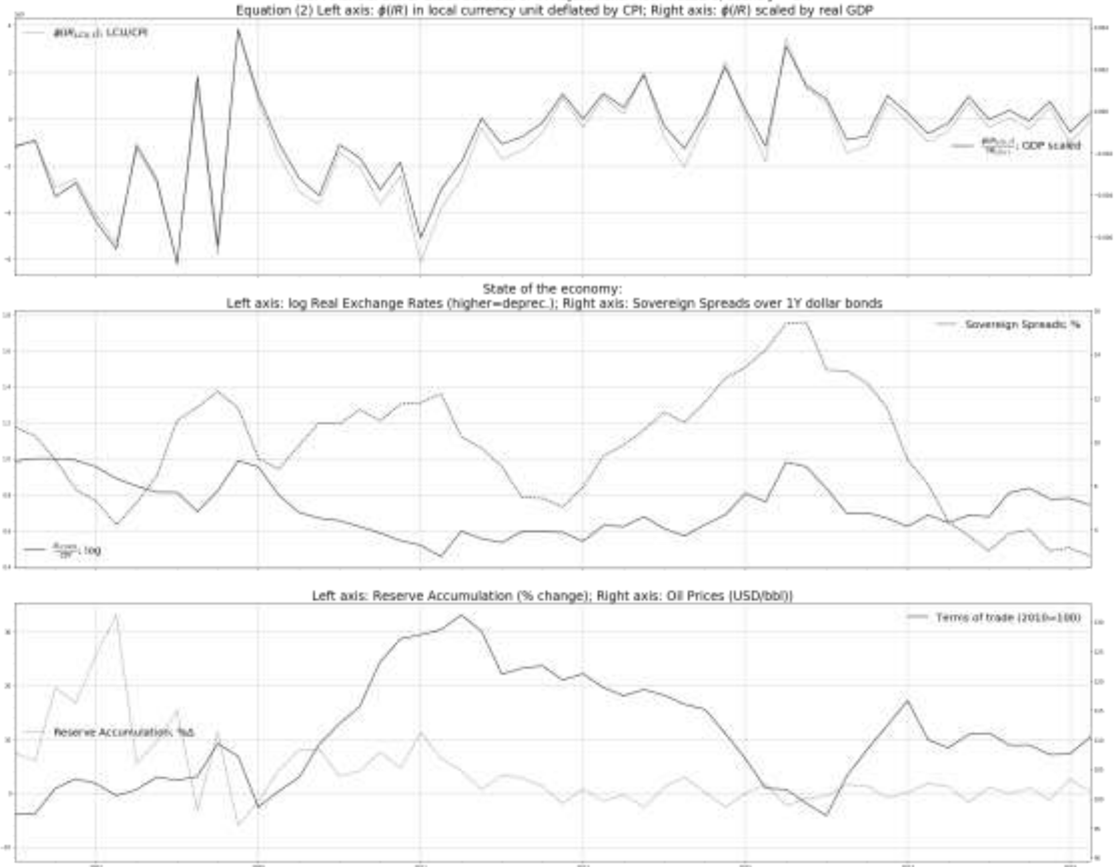


Figure 2. Financial Buffer Stock Services of IR Adjustment: Flow measure

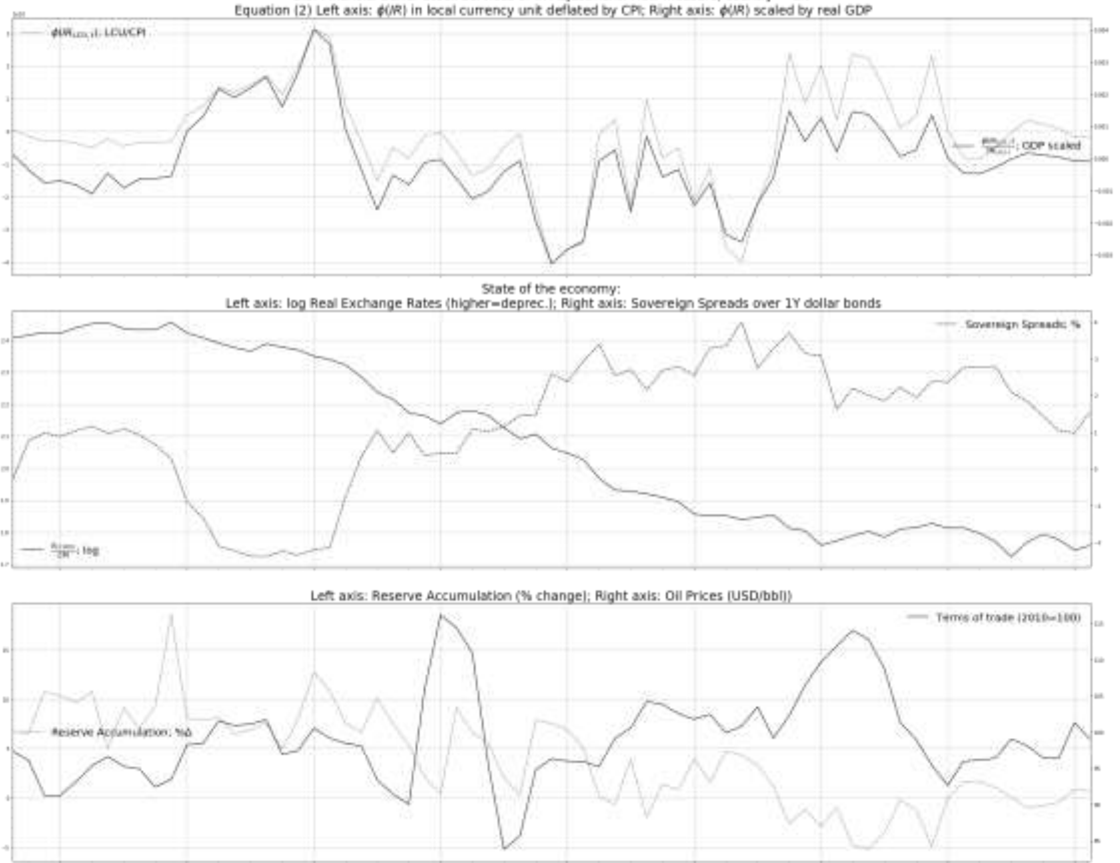
Note: Based on equation (2), the top panel left scale in the dotted .. curve is $\phi(IR)$ in real LCU (deflated by CPI), where CPI at the year 2010 was 100. The top panel right scale in the solid curve is $\phi(IR)$ in terms of real GDP (YR); 0.02 is 2 percent of GDP in the corresponding year. For Russia, the figure plots Brent Crude (USD/bbl) for the terms of trade. The estimation uses sovereign spreads over weighted average global rates (USD, GBP, JPY, EUR). Reserve accumulation (% change): $100 * [IR_t - IR_{t-1}]/IR_{t-1}$. Source: Thomson Reuters Eikon API.



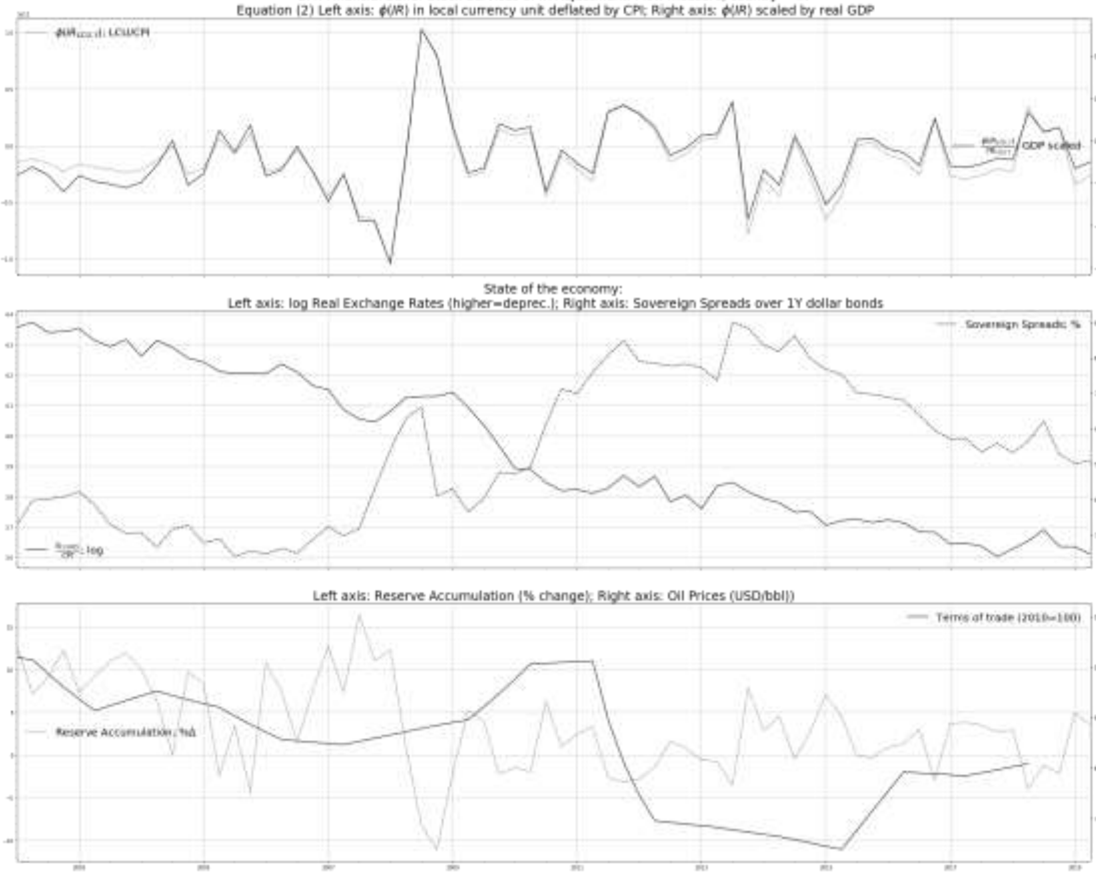
2.2. Financial Buffer Stock Services of IR Adjustment: Flow measure, country = BR
Equation (2) Left axis: $\phi(I/R)$ in local currency unit deflated by CPI; Right axis: $\phi(I/R)$ scaled by real GDP



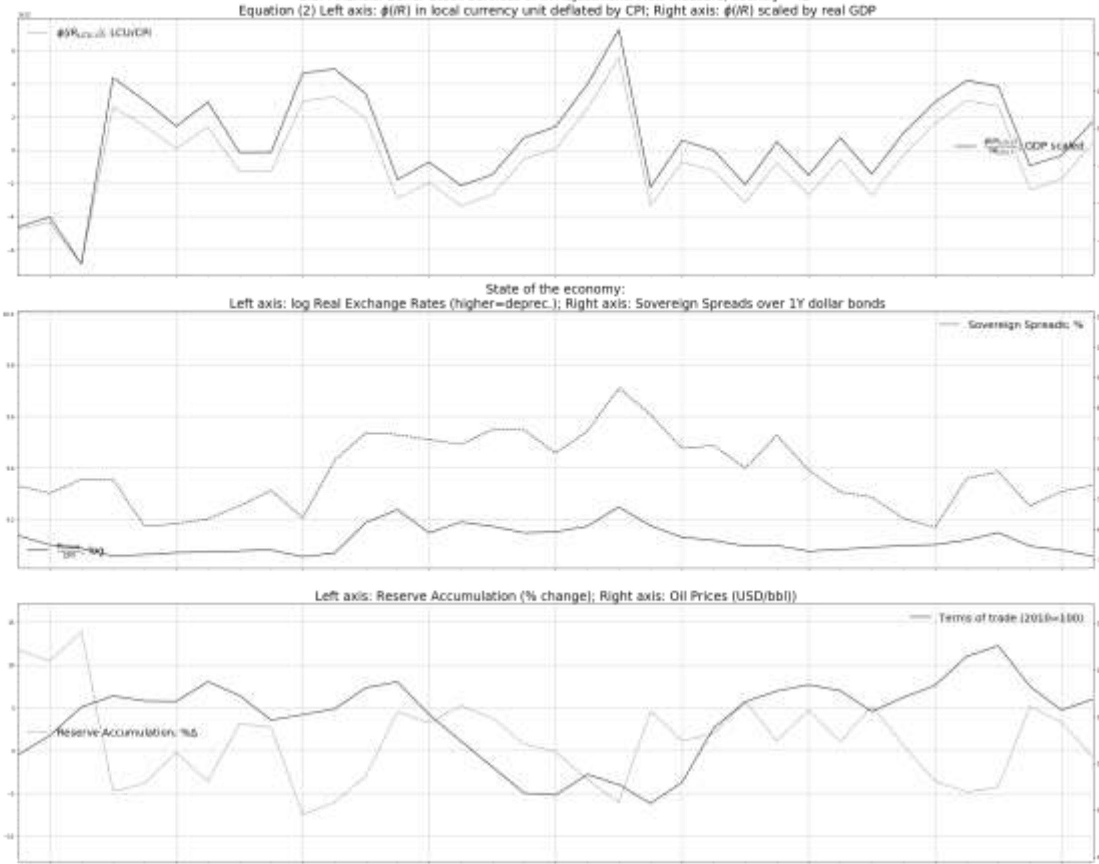
2.3. Financial Buffer Stock Services of IR Adjustment: Flow measure, country = CN
Equation (2) Left axis: $\phi(I/R)$ in local currency unit deflated by CPI; Right axis: $\phi(I/R)$ scaled by real GDP



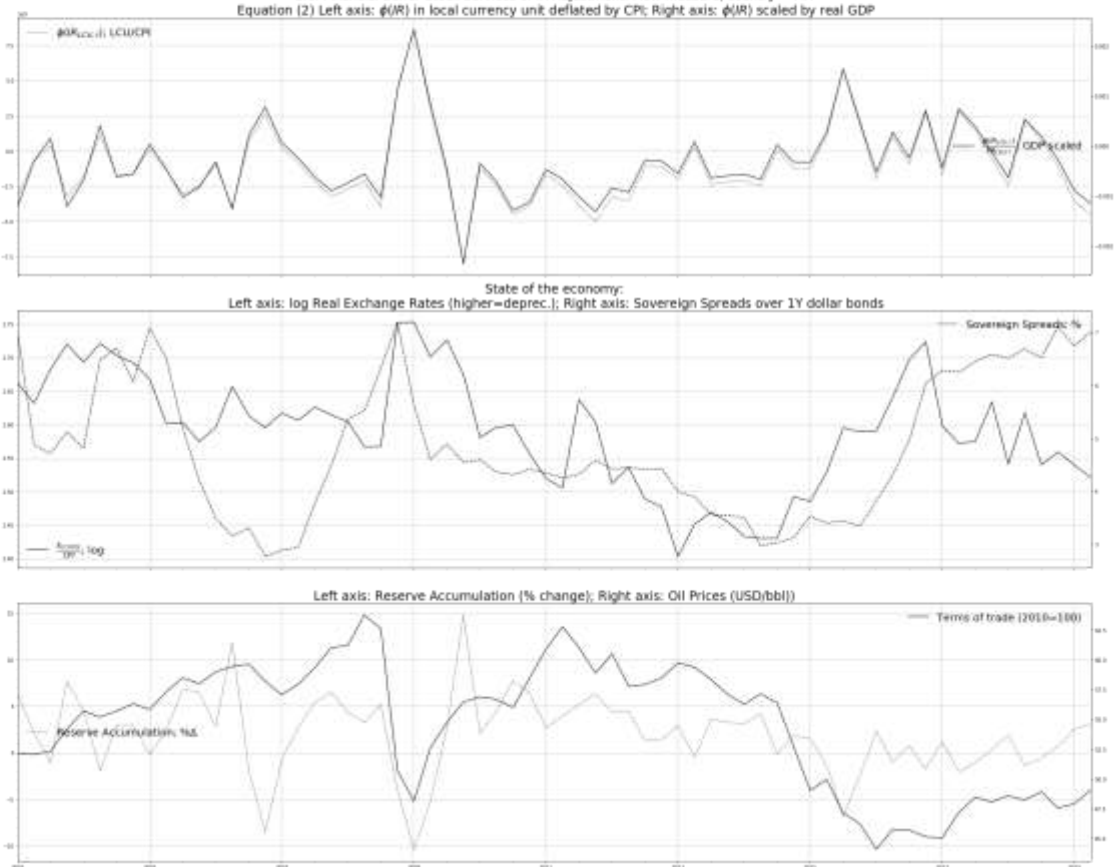
2.4. Financial Buffer Stock Services of IR Adjustment: Flow measure, country = IN
Equation (2) Left axis: $\phi(I/R)$ in local currency unit deflated by CPI; Right axis: $\phi(I/R)$ scaled by real GDP



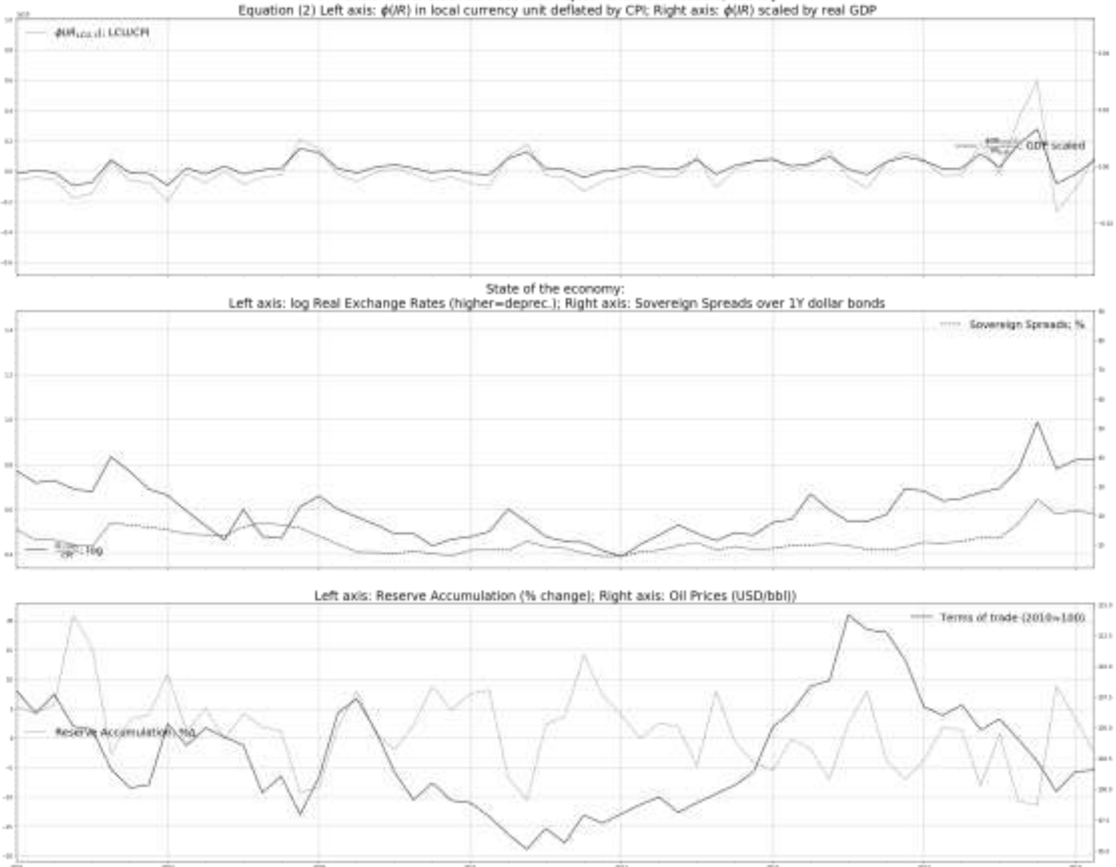
2.5. Financial Buffer Stock Services of IR Adjustment: Flow measure, country = ID
Equation (2) Left axis: $\phi(I/R)$ in local currency unit deflated by CPI; Right axis: $\phi(I/R)$ scaled by real GDP



2.6. Financial Buffer Stock Services of IR Adjustment: Flow measure, country = MX
Equation (2) Left axis: $\phi(IR)$ in local currency unit deflated by CPI; Right axis: $\phi(IR)$ scaled by real GDP



2.7. Financial Buffer Stock Services of IR Adjustment: Flow measure, country = TR
Equation (2) Left axis: $\phi(IR)$ in local currency unit deflated by CPI; Right axis: $\phi(IR)$ scaled by real GDP



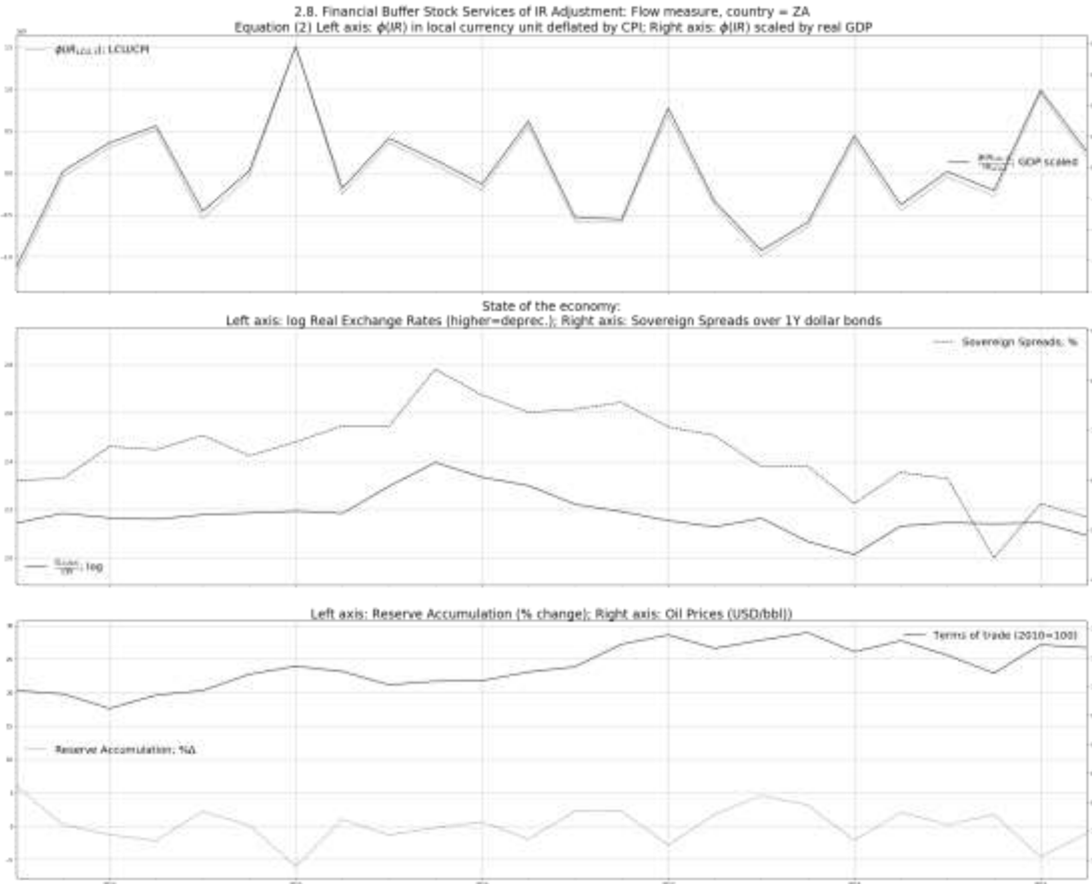
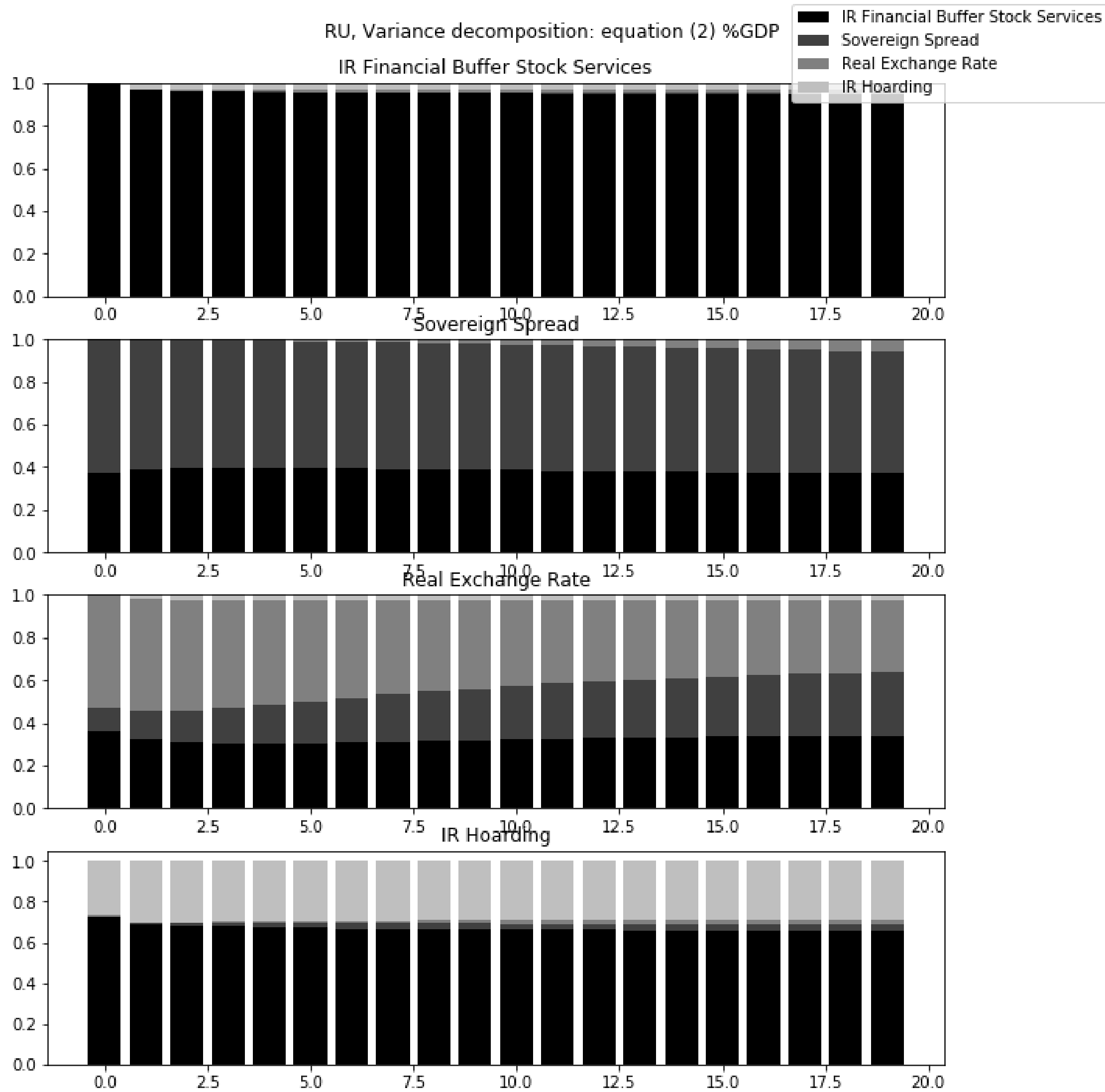
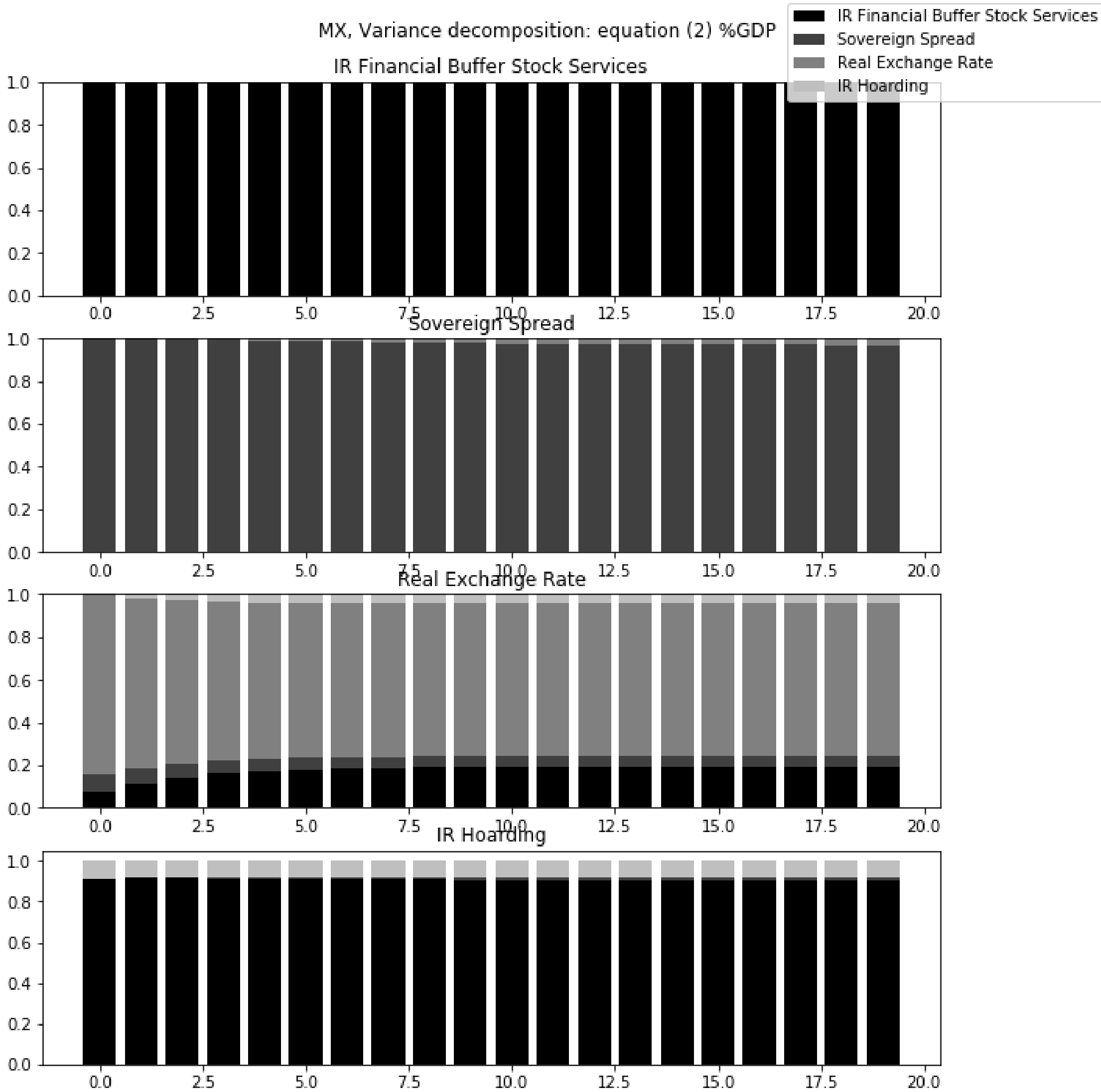
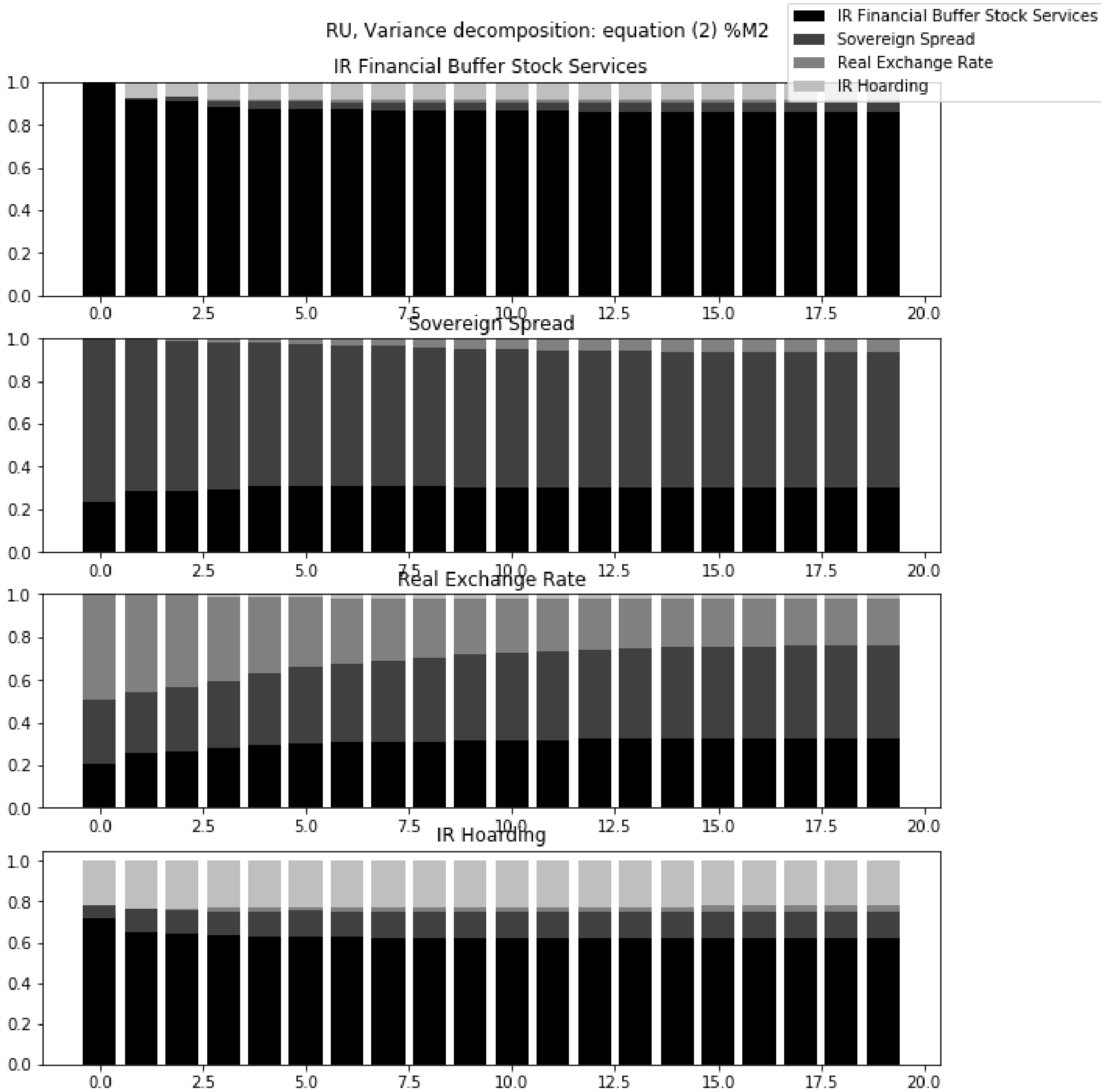

2.8. Financial Buffer Stock Services of IR Adjustment: Flow measure, country = ZA
Equation (2) Left axis: ϕ(IR) in local currency unit deflated by CPI; Right axis: ϕ(IR) scaled by real GDP
State of the economy:
Left axis: log Real Exchange Rates (higher=deprec.); Right axis: Sovereign Spreads over 1Y dollar bonds
Sovereign Spreads, %
Left axis: Reserve Accumulation (% change); Right axis: Oil Prices (USD/bbl))
Terms of trade (2010=100)
Reserve Accumulation; %Δ

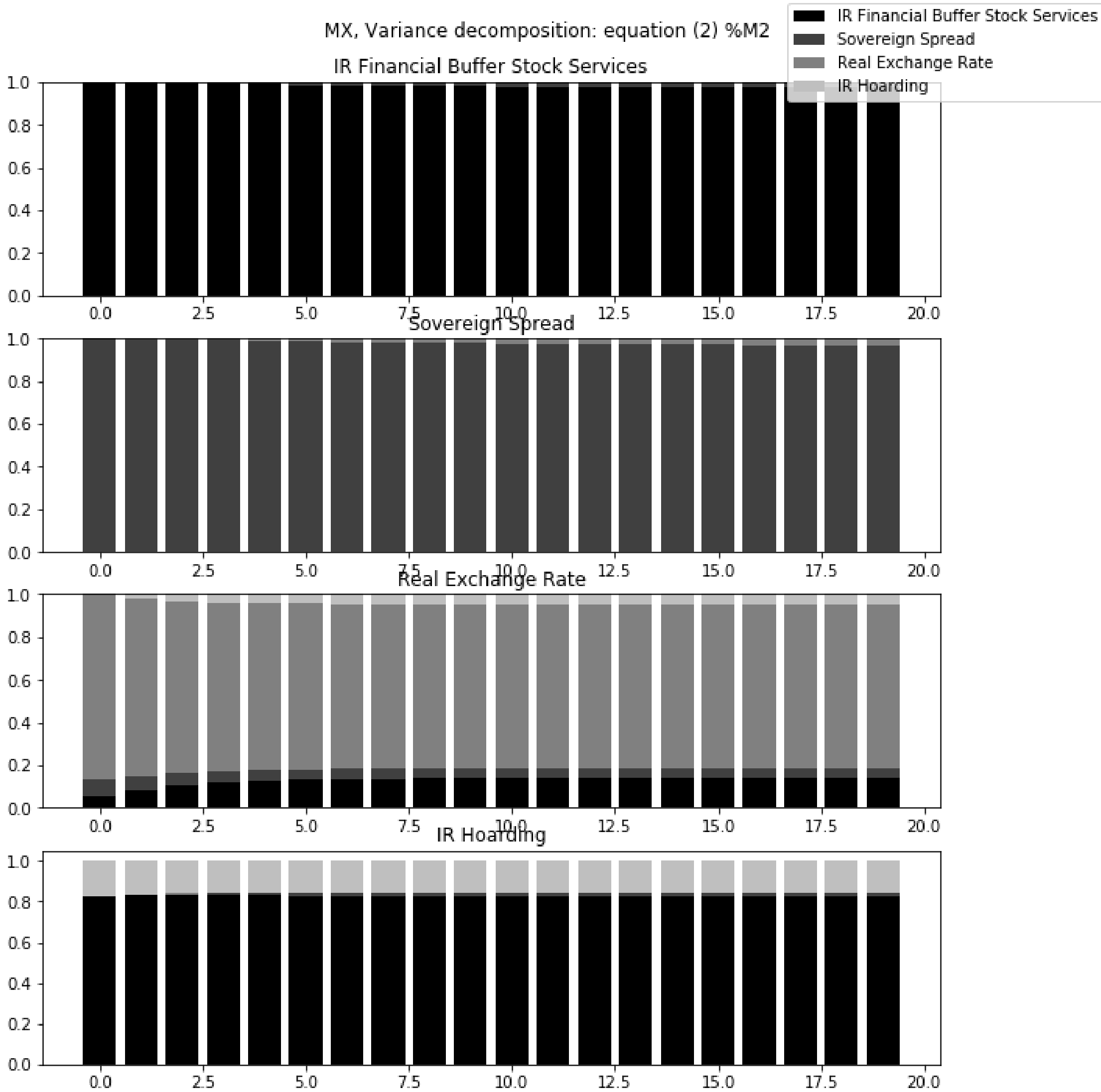
Figure 3. Variance decomposition of IR financial buffer stock services as % of GDP and as % of M2

These figures plot the forecast error variance decomposition (FEVD) for the IR financial buffer stock services of equation (2; a flow measure, % of GDP in the top panel and % of M2 in the bottom panel), according to the variance decomposition specified in equations (4) and (5) for Russia and Mexico.




MX, Variance decomposition: equation (2) %GDP
IR Financial Buffer Stock Services
Sovereign Spread
Real Exchange Rate
IR Hoarding
IR Financial Buffer Stock Services
Sovereign Spread
Real Exchange Rate
IR Hoarding
1.0
0.8
0.6
0.4
0.2
0.0
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0


RU, Variance decomposition: equation (2) %M2
IR Financial Buffer Stock Services
Sovereign Spread
Real Exchange Rate
IR Hoarding
1.0
0.8
0.6
0.4
0.2
0.0
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
Sovereign Spread
Real Exchange Rate
IR Hoarding


MX, Variance decomposition: equation (2) %M2
IR Financial Buffer Stock Services
Sovereign Spread
Real Exchange Rate
IR Hoarding
1.0
0.8
0.6
0.4
0.2
0.0
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0

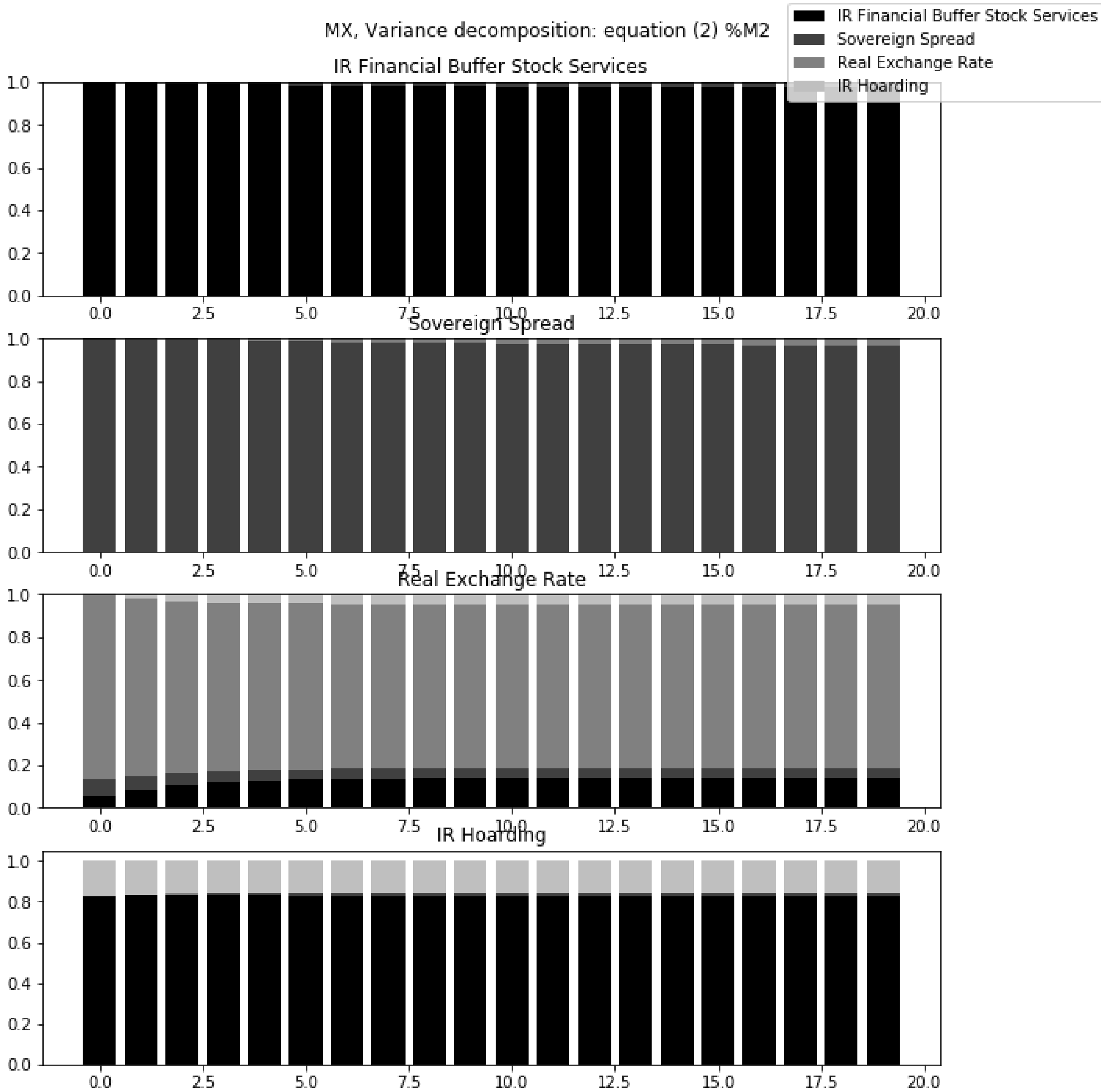
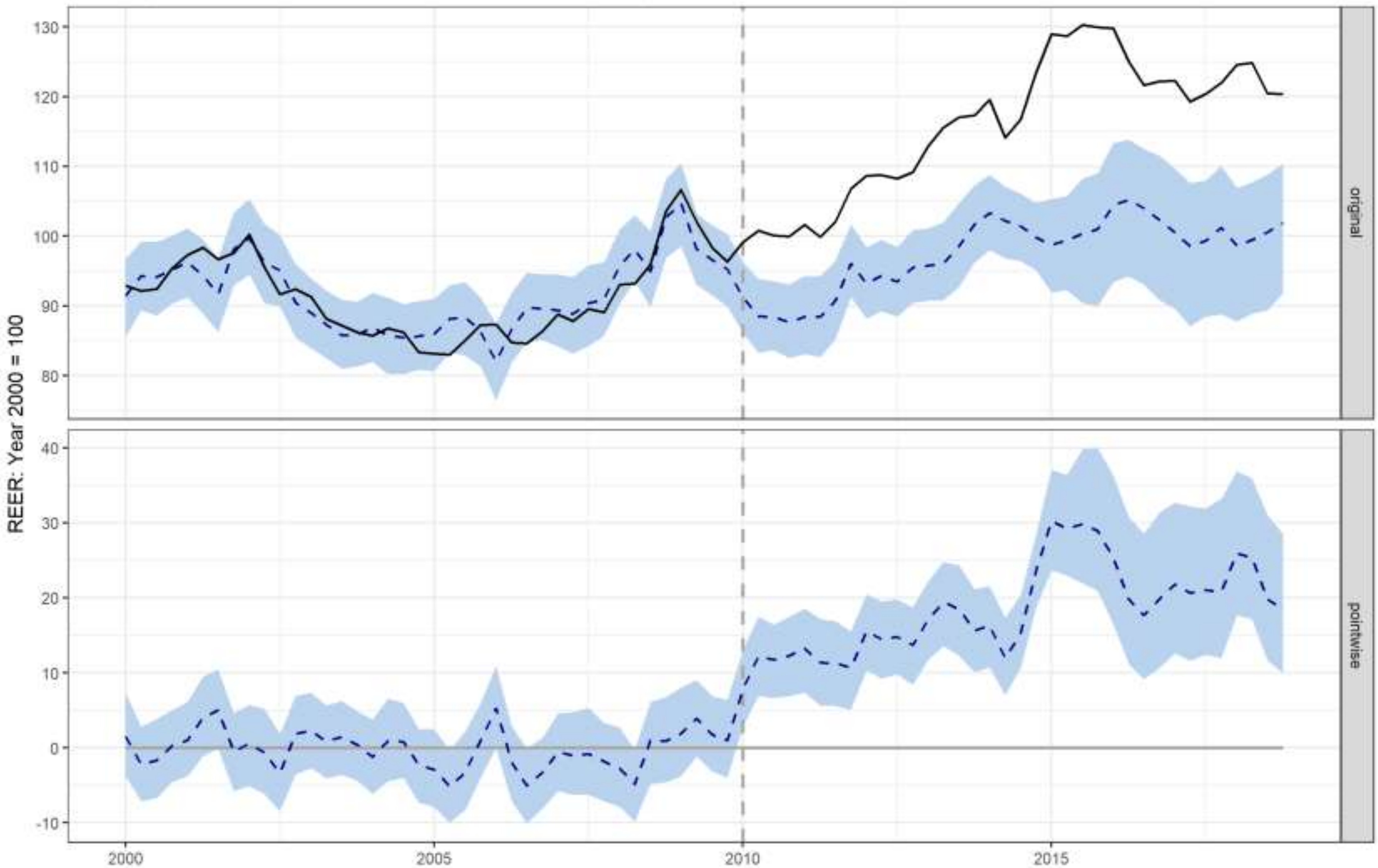

MX, Variance decomposition: equation (2) %M2
IR Financial Buffer Stock Services
Sovereign Spread
Real Exchange Rate
IR Hoarding
IR Financial Buffer Stock Services
Sovereign Spread
Real Exchange Rate
IR Hoarding
0.0
0.2
0.4
0.6
0.8
1.0
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0

Figure 4.1. Real effective exchange rates and Counterfactuals: Country = CN

Causal inference using Bayesian structural time-series models; pointwise causal effect.
The first panel shows the data and a counterfactual prediction for the post-treatment period.
The second panel shows the difference between observed data and counterfactual predictions.



Source: BIS statistics; CausalImpact - R package for causal inference:
https://cran.r-project.org/web/packages/CausalImpact/index.html

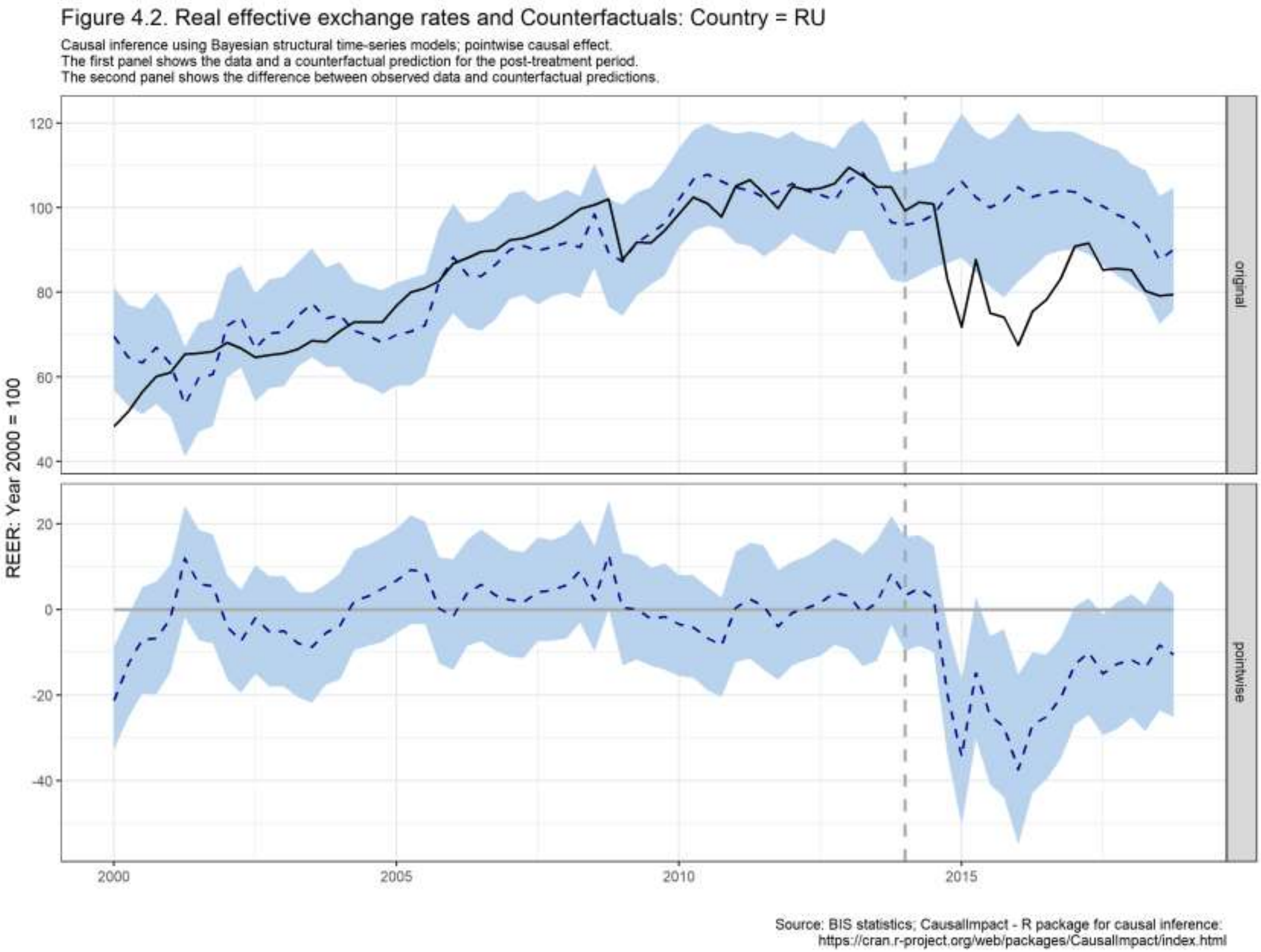
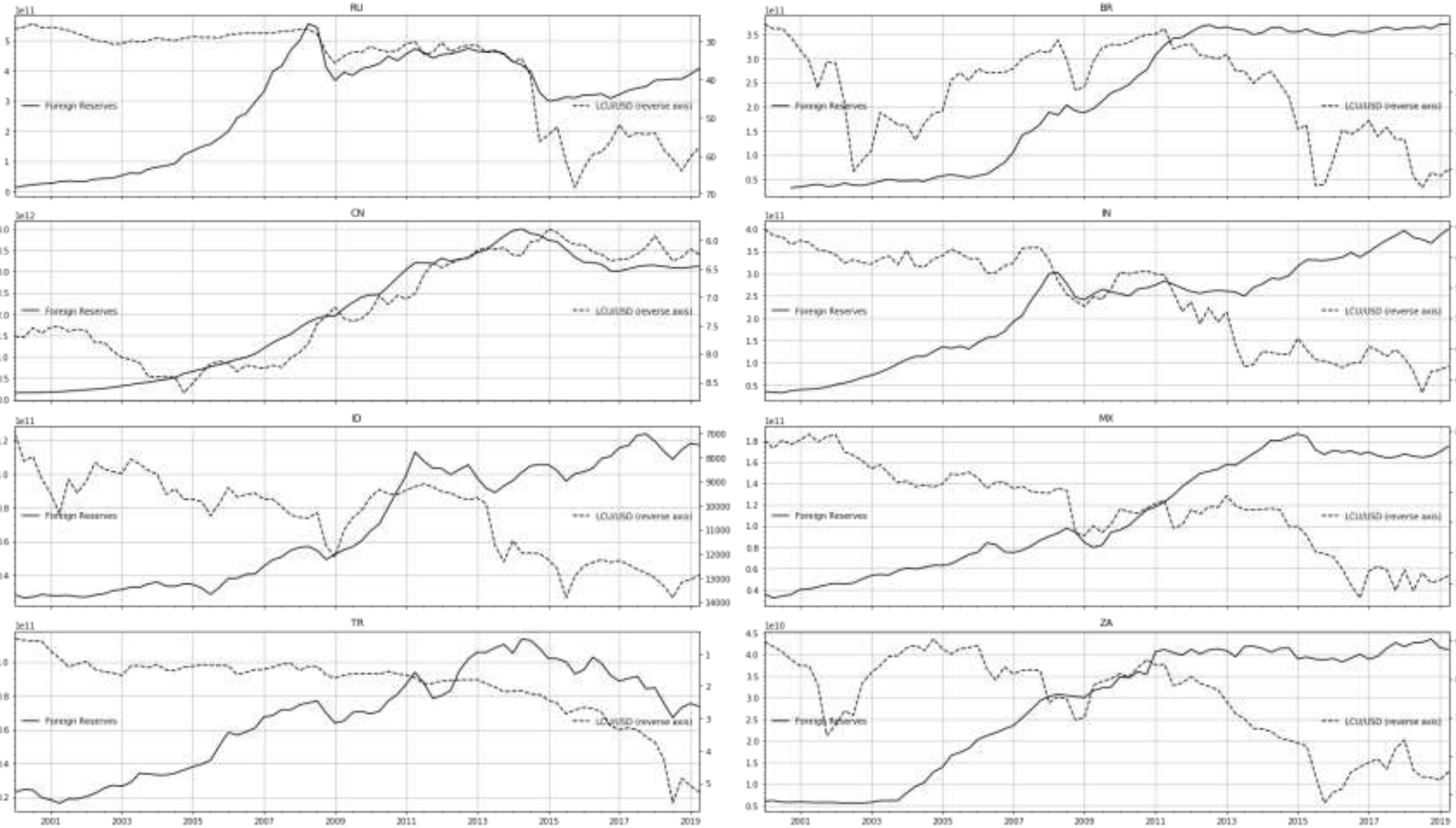


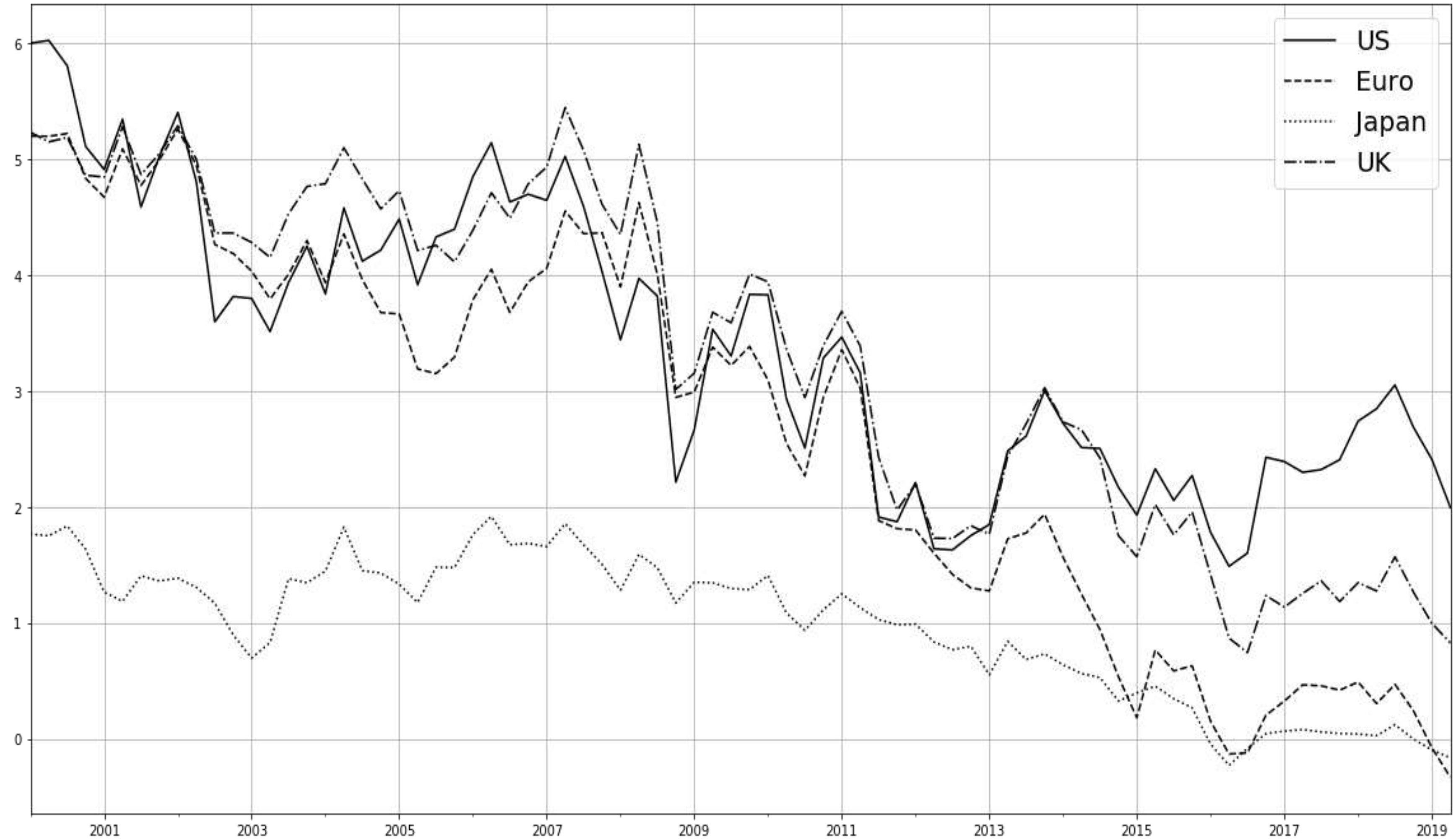
Figure 4.2. Real effective exchange rates and Counterfactuals: Country = RU
Causal inference using Bayesian structural time-series models; pointwise causal effect.
The first panel shows the data and a counterfactual prediction for the post-treatment period.
The second panel shows the difference between observed data and counterfactual predictions.
REER: Year 2000 = 100
120
100
80
60
40
20
0
-20
-40
original
pointwise
2000
2005
2010
2015
Source: BIS statistics; CausalImpact - R package for causal inference:
https://cran.r-project.org/web/packages/CausalImpact/index.html

Figure A1. International Reserves and Exchange Rates



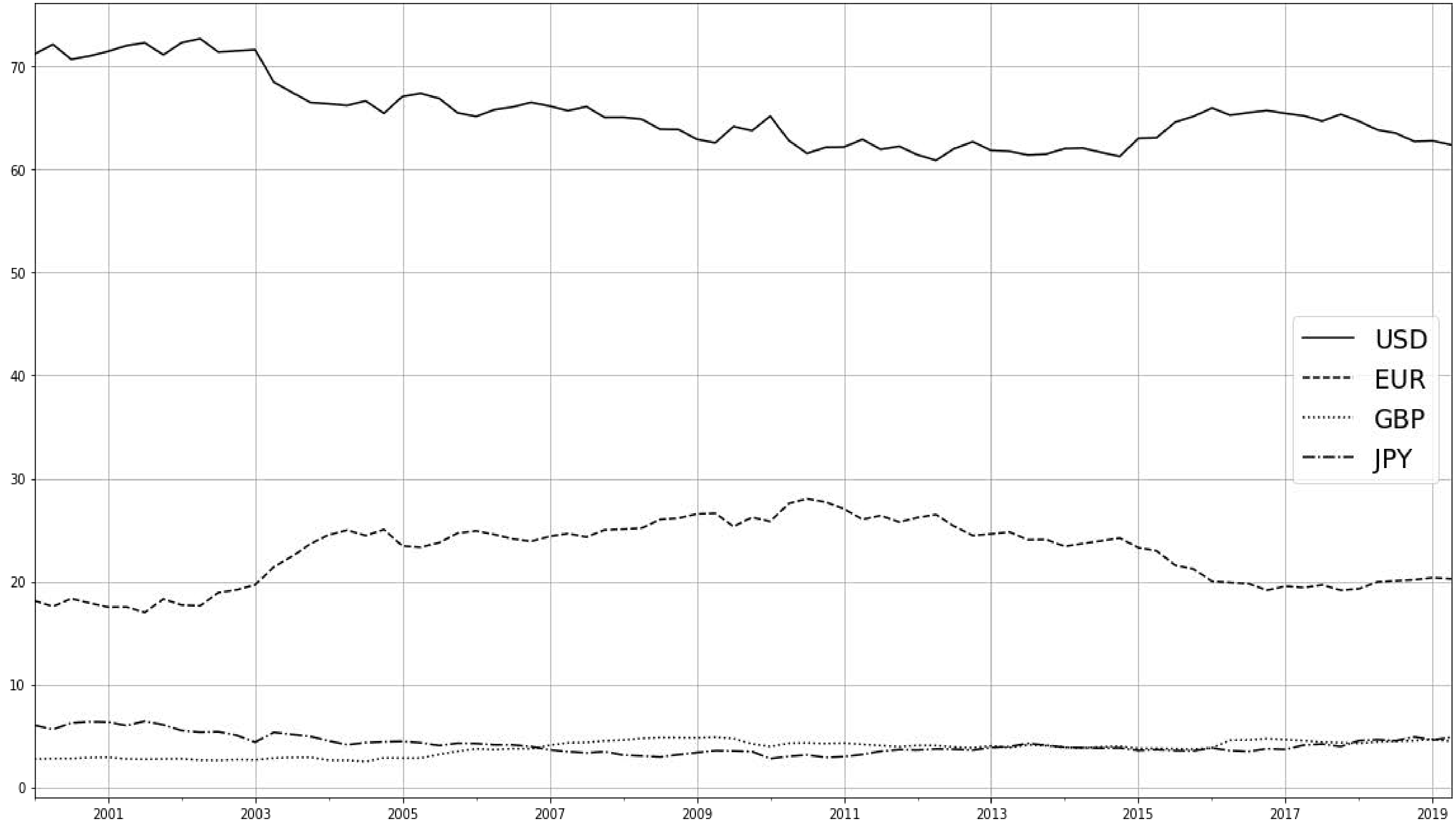
Note: International reserves in US$ (current prices, not seasonally adjusted), Exchange rates: local currency against USD (end of quarter); Source: Thomson Reuters Eikon API.

Figure A2. Government Bond Yields: US, Euro, Japan, and UK



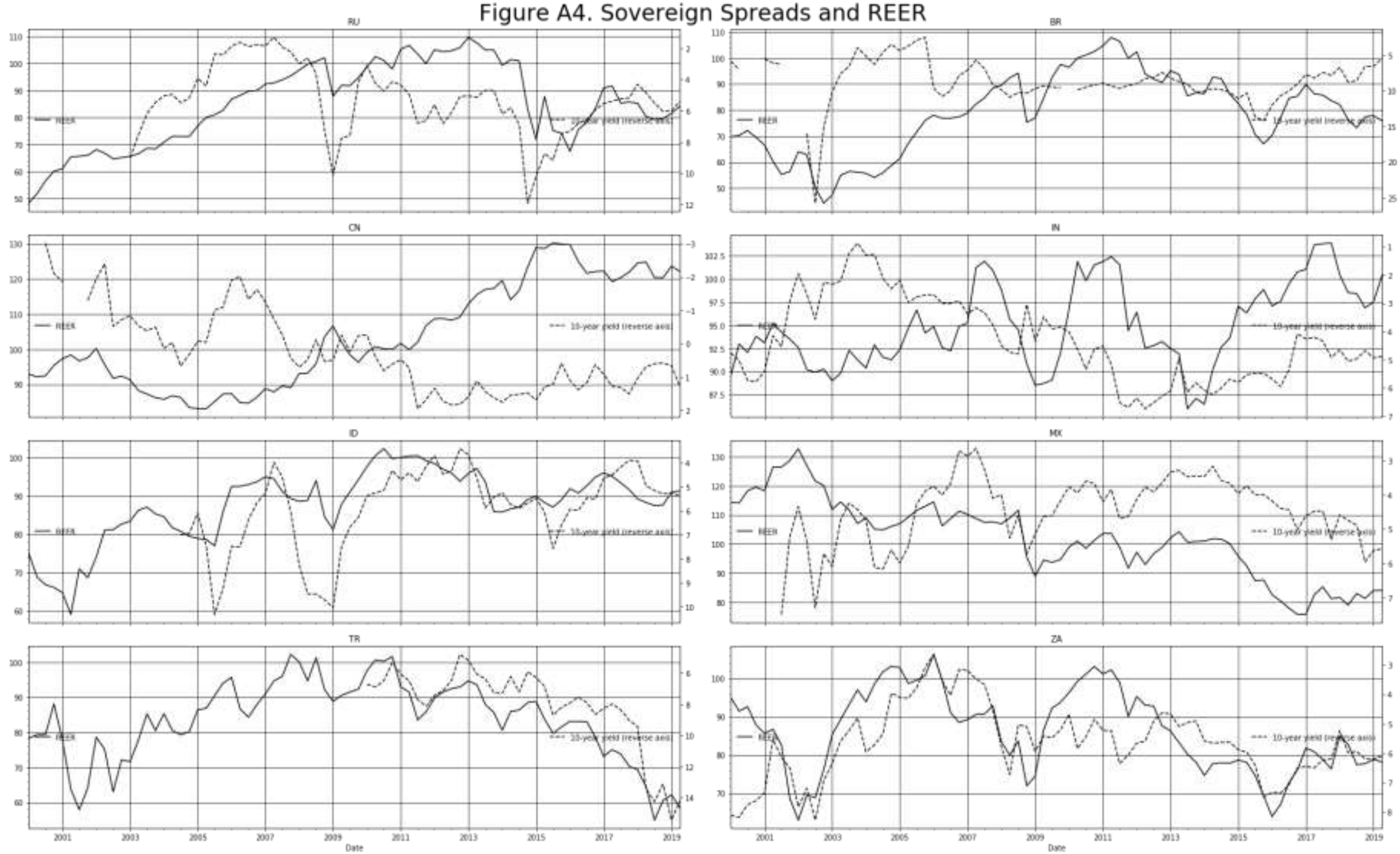
Note: Quarterly 10-year yields (%); Source: Thomson Reuters Eikon API.

Figure A3. Currency Composition of International Reserves



Note: % of Allocated reserves; Source: IMF COFER

Figure A4. Sovereign Spreads and REER



Note: Quarterly 10-year spreads over US Treasury (%), Trade-weighted REER (BIS); Source: Thomson Reuters Eikon API.

Table 1. Variance decomposition of Russia's IR financial buffer stock services (%GDP), 2003-2019

This table reports the forecast error variance decomposition (FEVD) for the IR financial buffer stock services of equation (2; a flow measure, % of GDP), according to the variance decomposition specified in equations (4) and (5) for Russia.

FEVD for IR Financial Buffer Stock Services

	IR Financial Buffer Services	Sovereign Spread	RER	IR Hoarding
0	1.000000	0.000000	0.000000	0.000000
1	0.969241	0.000633	0.002162	0.027965
2	0.961221	0.000739	0.004248	0.033792
3	0.959154	0.000754	0.005919	0.034172
4	0.957796	0.000771	0.007313	0.034120
5	0.956557	0.000816	0.008522	0.034105
6	0.955402	0.000906	0.009584	0.034108
7	0.954322	0.001048	0.010516	0.034114
8	0.953313	0.001240	0.011328	0.034119

FEVD for Sovereign Spread

	IR Financial Buffer Services	Sovereign Spread	RER	IR Hoarding
0	0.372347	0.627653	0.000000	0.000000
1	0.388685	0.609711	0.000536	0.001068
2	0.394205	0.602149	0.001700	0.001946
3	0.395590	0.598607	0.003412	0.002391
4	0.395226	0.596602	0.005613	0.002559
5	0.394017	0.595151	0.008247	0.002584
6	0.392357	0.593847	0.011250	0.002546
7	0.390449	0.592515	0.014553	0.002484
8	0.388417	0.591080	0.018081	0.002421

FEVD for Real Exchange Rate

	IR Financial Buffer Services	Sovereign Spread	RER	IR Hoarding
0	0.362223	0.110370	0.527408	0.000000
1	0.327609	0.126700	0.530925	0.014766
2	0.310684	0.145077	0.522062	0.022177
3	0.304416	0.163005	0.507220	0.025358
4	0.303667	0.179601	0.489917	0.026815
5	0.305610	0.194703	0.472160	0.027527
6	0.308780	0.208364	0.454986	0.027869
7	0.312428	0.220687	0.438884	0.028001
8	0.316162	0.231775	0.424056	0.028006

FEVD for IR Hoarding

	IR Financial Buffer Services	Sovereign Spread	RER	IR Hoarding
0	0.728127	0.000745	0.001810	0.269319
1	0.690217	0.004658	0.004045	0.301079
2	0.681534	0.010836	0.005795	0.301835
3	0.677099	0.016546	0.007310	0.299045
4	0.673776	0.020837	0.008775	0.296612
5	0.671177	0.023797	0.010245	0.294780
6	0.669105	0.025741	0.011718	0.293436
7	0.667419	0.026959	0.013170	0.292452
8	0.666022	0.027674	0.014580	0.291724

Table 2. Granger causality tests of Russia's IR financial buffer stock services

This table reports Granger causality tests of all possible combinations of the time series with a maximum of 4 lags (quarters). The rows are the response variable, and the columns are the predictors. The values in the table are the p-values, of which lesser than the significance level (0.05) implies the null hypothesis that the coefficients of the corresponding past values are zero, that is, the x (predictor, in columns) does not cause (does not improve the forecasting performance of) y (response, in rows) can be rejected. The IR financial buffer stock services are based on equation (2); a flow measure, % of GDP, and % of M2.

2.1. IR Financial Buffer Stock Services %GDP

Russia:

	IR Financial Buffer Stock Services(x)	Sovereign Spread (x)	Real Exchange Rate (x)	IR Hoarding (x)
IR Financial Buffer Stock Services (y)	1.0000	0.1194	0.0108	0.1026
Sovereign Spread (y)	0.3123	1.0000	0.0293	0.3216
Real Exchange Rate (y)	0.1647	0.1808	1.0000	0.1030
IR Hoarding (y)	0.2896	0.2327	0.2442	1.0000

Mexico:

	IR Financial Buffer Stock Services (x)	Sovereign Spread (x)	Real Exchange Rate (x)	IR Hoarding (x)
IR Financial Buffer Stock Services (y)	1.0000	0.0000	0.0176	0.0894
Sovereign Spread (y)	0.0000	1.0000	0.1945	0.0000
Real Exchange Rate (y)	0.0000	0.0551	1.0000	0.0000
IR Hoarding (y)	0.3018	0.0000	0.0013	1.0000

2.2. IR Financial Buffer Stock Services %M2 Russia:

	IR Financial Buffer Stock Services (x)	Sovereign Spread (x)	Real Exchange Rate (x)	IR Hoarding (x)
IR Financial Buffer Stock Services (y)	1.0000	0.0788	0.0002	0.0019
Sovereign Spread (y)	0.0852	1.0000	0.0293	0.3216
Real Exchange Rate (y)	0.3453	0.1808	1.0000	0.1030
IR Hoarding (y)	0.0006	0.2327	0.2442	1.0000

Mexico:

	IR Financial Buffer Stock Services (x)	Sovereign Spread (x)	Real Exchange Rate (x)	IR Hoarding (x)
IR Financial Buffer Stock Services (y)	1.000	0.0000	0.0135	0.3612
Sovereign Spread (y)	0.000	1.0000	0.1945	0.0000
Real Exchange Rate (y)	0.000	0.0551	1.0000	0.0000
IR Hoarding (y)	0.324	0.0000	0.0013	1.0000

Table 3.1. IR flow services (%GDP)

$$\phi\left(IR_{i;t}\right) = \beta_0^1 + \beta_1^1(IR\ accu)_{i;t} + \beta_1^1(Sov\ sprd)_{i;t} + \beta_1^1(E/CPI)_{i;t} + \varepsilon_{i;t}^1$$

	BR	CN	IN	ID	MX	RU	TR	ZA
IR accu	-0.97***	-0.45***	-0.95***	-0.96***	-0.95***	-0.90***	-0.87***	-1.00***
	(0.04)	(0.06)	(0.04)	(0.04)	(0.05)	(0.08)	(0.07)	(0.03)
Sov sprd	-0.01	-0.94***	-0.16***	0.01	-0.05	-0.14*	0.03	-0.08**
	(0.04)	(0.08)	(0.05)	(0.05)	(0.05)	(0.08)	(0.07)	(0.04)
E/CPI	-0.04	-0.27***	-0.23***	0.07	-0.03	-0.11	0.05	0.06
	(0.04)	(0.08)	(0.05)	(0.05)	(0.06)	(0.07)	(0.07)	(0.04)
N	52	67	68	33	64	70	56	22
R2	0.92	0.78	0.90	0.95	0.87	0.73	0.81	0.98

OLS Estimation (standardized variables: mean=0, standard deviation=1). Standard errors in parentheses.
* p<.1, ** p<.05, ***p<.01
Brazil: 2006Q1-; China: 2002Q2-; India: 2002Q1-; Indonesia: 2003Q2-;
Mexico: 2003Q1-; Russia: 2001Q3-; Turkey: 2005Q1-; South Africa: 2013Q3-2019Q1.

Table 3.2. IR cumulated flow services (%IR)

$$\Phi(IR_{RU;t_1 \ldots t_2}) = \beta_0^2 + \beta_1^2(IR\ accu)_{i;t} + \beta_1^2(Sov\ sprd)_{i;t} + \beta_1^2(E/CPI)_{i;t} + \varepsilon_{i;t}^2$$

	BR	CN	IN	ID	MX	RU	TR	ZA
IR accu	-0.60***	0.37***	-0.10*	-0.30**	-0.20	0.04	-0.23	-0.31
	(0.12)	(0.08)	(0.06)	(0.15)	(0.13)	(0.09)	(0.14)	(0.20)
Sov sprd	0.02	-0.88***	-0.22***	-0.19	-0.23*	0.51***	-0.11	-0.39
	(0.11)	(0.10)	(0.08)	(0.17)	(0.13)	(0.10)	(0.15)	(0.24)
E/CPI	-0.37***	-0.76***	-1.01***	0.56***	-0.22	-0.83***	-0.24	0.52**
	(0.12)	(0.10)	(0.08)	(0.17)	(0.15)	(0.08)	(0.16)	(0.24)
N	52	67	68	33	64	70	56	22
R2	0.36	0.60	0.79	0.40	0.14	0.62	0.10	0.28

OLS Estimation (standardized variables: mean=0, standard deviation=1). Standard errors in parentheses.
* p<.1, ** p<.05, ***p<.01
Brazil: 2006Q1-; China: 2002Q2-; India: 2002Q1-; Indonesia: 2003Q2-;
Mexico: 2003Q1-; Russia: 2001Q3-; Turkey: 2005Q1-; South Africa: 2013Q3-2019Q1.

Table 3.3. IR cumulated flow services + opportunity costs (%IR)

$$\Gamma(IR_{RU;t_1 \ldots t_2}) = \beta_0^3 + \beta_1^3 (IR\ accu)_{i;t} + \beta_1^3 (Sov\ sprd)_{i;t} + \beta_1^3 (E/CPI)_{i;t} + \varepsilon_{i;t}^3$$

	BR	CN	IN	ID	MX	RU	TR	ZA
IR accu	0.22**	0.46***	0.06	-0.31**	-0.21	-0.06	-0.27*	-0.29
	(0.10)	(0.08)	(0.11)	(0.15)	(0.13)	(0.05)	(0.14)	(0.20)
Sov sprd	-0.44***	-0.70***	-0.71***	-0.18	-0.24*	-0.15***	-0.15	-0.43*
	(0.10)	(0.10)	(0.14)	(0.17)	(0.13)	(0.05)	(0.15)	(0.25)
E/CPI	0.60***	-0.20*	-0.49***	0.54***	-0.21	-0.88***	-0.21	0.51*
	(0.10)	(0.11)	(0.14)	(0.17)	(0.15)	(0.04)	(0.16)	(0.24)
N	52	67	68	33	64	70	56	22
R2	0.55	0.59	0.30	0.38	0.14	0.89	0.11	0.27

OLS Estimation (standardized variables: mean=0, standard deviation=1).
Standard errors in parentheses. * p<.1, ** p<.05, ***p<.01
Brazil: 2006Q1-; China: 2002Q2-; India: 2002Q1-; Indonesia: 2003Q2-;
Mexico: 2003Q1-; Russia: 2001Q3-; Turkey: 2005Q1-; South Africa: 2013Q3-2019Q1.

Table 4. Share of commodities and the effects of RER variation on IR buffer-stocks services

	BR	CN	IN	ID	MX	RU	TR	ZA
b[E/CPI]: : $\phi\left(IR_{i;t}\right)$	0.00	-0.27	-0.23	0.00	0.0	0.00	0.0	0.00
b[E/CPI]: $\Phi(IR_{RU;t_1 \dots t_2})$	-0.37	-0.76	-1.01	0.56	0.0	-0.83	0.0	0.52
b[E/CPI]: : $\Gamma(IR_{RU;t_1 \dots t_2})$	0.60	-0.20	-0.49	0.54	0.0	-0.88	0.0	0.51
Commodity exports/GDP(%)	6.50	2.10	10.70	5.70	6.1	17.10	4.5	13.20
Commodities/exports(%)	63.00	8.00	58.00	42.00	19.0	74.00	23.0	55.00

Note: Statistically insignificant at 10% b[E/CPI] is reported as zero.
Based on the OLS (Table 1), standardized variables.
Specification: IR buffer services (Y) = f(IR accu.,Sov. sprd., RER=E/CPI);
Share of commodity exports are from UNCTAD.

Table 5. Causal Impact of IR on REER: China and Russia

We study two IR policy changes: China's 2010Q2 and Russian's 2014Q2. The estimated average causal effect of China's IR 2010Q2 policy intervention treatment was 19 (an appreciation): the actual (average) value is 116 and the predicted (average) value is 98. The 90 percent posterior interval of the average effect is [15, 23]; See also Figure 4.1. The estimated average causal effect of Russia's IR 2014Q2 policy intervention treatment was -17 (a depreciation): the actual (average) value is 83 and the predicted (average) value is 100. The 90 percent posterior interval of the average effect is [-24, -7]; See also Figure 4.2.

	China		Russia	
	Average	s.e.	Average	s.e.
Actual REER	116.0	0.0	83.0	0.0
Predicted REER	98.0	2.5	100.0	5.1
	Average	s.e.	Average	s.e.
Absolute eff.	19.0	2.5	-17.0	5.1

Sample period is 2002Q2-2019Q1.
Pre-treatment period is 2002Q2-2010Q1.
Controls: BR, (CN,) IN, ID, MX, (RU,) TR, ZA.