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ABSTRACT

This paper outlines a tractable cost-benefit analysis of the buffers stock financial services provided by international reserves, and applies it to 8 of the largest Emerging Markets (BRICS, Indonesia, Mexico, Turkey) during 2000Q1-2019Q1. 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. 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.

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1. Introduction

Successful buffer stock management of international reserves provides two related financial services. First, it mitigates financial fragility associated with balance sheet exposure to maturing foreign debt, a role highlighted by Rodrik (2006), Aizenman and Lee (2007), and modeled more recently in the context of stabilizing exposure to multiple equilibria by Bocola and Lorenzoni (2017). The second benefit is 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 hedging exposure to roll-over risks as discussed in Bianchi, Hatchondo, and Martinez (2012). We outline below a framework accounting for this intertemporal aspect of managing reserves, transferring purchasing power from times of relative plenty to stormy, leaner times. It provides a tractable way to quantify the welfare costs and benefits of an active flow policy of hoarding international reserves (henceforth IR) in good times, and selling IR in bad times.

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 more properly measured in terms of the domestic purchasing power, obtained by multiplying the dollar opportunity cost with the real exchange rate (i.e., the domestic 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.[1] Section 2 presents data and preliminary analysis using Russia as a case study. Section 3 follows with a comparative analysis of the largest eight emerging-market countries, and concludes with a short case study of China and Russia. Section 4 provides concluding remarks.

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[1] Theoretical models outline the basis for this association are in Aizenman and Marion (2004) and Aizenman, Kletzer, and Pinto (2005).

2. Empirical Analysis

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, taking into account systemically-important borrowers (i.e. large banks, state and prime borrowers).[2] Russia is a prime example of this scenario in the 2000s-2010s. After discussing the data, we proceed with a preliminary analysis using Russia as a case study. Our data is comprised of international reserves, nominal exchange rates, real exchange rates, sovereign bond yields, external debt, imports, and monetary base. We use quarterly data from 2000Q1 to 2019Q1. Next, we consider the largest emerging markets comprised of BRICS+3: Brazil, China, India, Indonesia, Mexico, Russia, South Africa, and Turkey. Appendix Figure A1 provides the time profile of international reserves and exchange rates of countries in our sample. We use Eikon API to extract quarterly data from Thomson Reuters. These macroeconomic series are based on statistical reports of national agencies and international financial organizations. Necessary statististics are then calculated from these quarterly series.

Flow and stock IR management policies – definitions and measurement: Russia case study

We illustrate the cumulative benefit of an active buffer stock policy for a prime commodity-exporting country, Russia. For a commodity country, stronger terms of trade (higher dollar prices of oil in the case of Russia) is associated with stronger Ruble, rising foreign currency oil revenue, and lower sovereign spreads, while the reserve applies at times of lower prices of oil. These cycles influence the net benefits of IR accumulation.[3]

We estimate both the flow and stock measures of IR buffer services. We denote the exchange rate, the ruble price of a dollar at time t, by $E_{RU/USD;t}$; Russia CPI at time t by $CPI_{RU,t}$; and the

[2] Examining data from 1815-2017 covering 88 countries, Meyer, Reinhart, and Trebesch (2018) find an average excess return of external sovereign bonds above US government bonds is 4 percent, and that the sovereign bonds outperform corporate bonds and stocks. In light of this evidence, we take the demand for sovereign debt and the sovereign premia as given, and study the benefits of IR buffer stock management from the perspective of a debtor country.

[3] See Algieri (2013) for a case study of the Russian real exchange rate determination in the context of oil prices and international reserves management. Qian and Steiner (2017) shows that reserves management increase the share of long-term in total external debt, reinforcing financial stability. Bhattacharya, Mann, and Nkusu (2018) confirms empirically the importance of terms of trade volatility in accounting for the demand of international reserves by emerging markets economies.

sovereign spread on Russia hard currency debt by $i_{RUD;t} - i_{USD;t}$, i is the interest rate, RUD is Russia dollar debt, and USD is US debt for comparable maturity (see also Appendix Figure A2 for the time profile of US interest rates, together with the interest rates of Euro, Japan, and UK). The real opportunity cost of buying international reserves, evaluated by the CPI at time t is[4]

$$(1) \qquad \phi(IR_{RU;t}) = -\Delta IR_{RU,t}(i_{RUD;t} - i_{USD;t})\frac{E_{RU/USD,t}}{CPI_{RU,t}}$$

where $\Delta IR_{RU,t}$ is the increase of international reserves at time t (its negative values correspond to selling international reserves), and the negative sign stands for the cost. Equation (1) also measures the marginal benefit associated with selling international reserves, as will be the case when $\Delta IR_{RU,t}$ is negative.

The top panel of Figure 1.1 summarizes the flow policies of Russia from 2001 to 2019. It shows the flow costs of hoarding IR, defined by equation 1, evaluated at the real exchange rate [dotted line, left scale, plotting $\phi(IR_{RU;t})$] ; and scaled by the Russian real GDP, $YR_{RU,t}$ [solid line, right scale, plotting $\phi(IR_{RU;t})/YR_{RU,t}$]. The middle panel traces the log of the real exchange rate (solid line, left scale, higher values implies weaker ruble), and the percentage sovereign spreads (solid line, right scale). The bottom panel provides the percentage accumulation of international reserves (dotted line, left scale), and the price of oil (solid line, right scale).

The price of oil increased in the early 2000s from, from about 30 USD to 140 USD prior to the global financial crisis. During that period, the ruble appreciated, and the central bank increased its international reserves rapidly, reaching more than 600 Billion USD. The opportunity cost of this accumulation, traced in the top panel, was well below 1/3 percent of the GDP during most of this period. In contrast, during the worst part of the GFC, more than 200 Billion US$ international reserves were sold at times of sharply depreciated ruble and rapidly rising spreads, providing sizable flow benefits, reaching more than 2 percent of the Russian GDP. Similar patterns applied from 2010, 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

[4] Our working assumption is that all hard currency debt is dollar denominated. This presumption reflects the global dominance of the dollar as the funding currency of external debt, and the absence of detailed data on the actual currency composition of Emerging Markets external debt.

spreads, funding thereby the reduction of hard currency external debt by IR that were accumulated in times of plenty (i.e., rising oil prices, appreciating ruble, and declining sovereign spreads).

Cumulated flows of financial buffer stock services

The discounted sum of all the changes of international reserves in equation (1) provides us the n.p.v. of the flow management benefits of IR overtime. Specifically, the cumulated financial buffer flow services attributed to selling and buying during IR during periods $t_1 \cdots t_2$, denoted by $\Phi(IR_{RU;t_1...t_2})$, is

$$(2) \qquad \Phi(IR_{RU;t_1...t_2}) = -\sum_{t_1}^{t_2} \frac{1}{(1+\rho)^t} \left[\Delta IR_{RU,t} \frac{E_{RU/USD,t}}{CPI_{RU,t}} \right] (i_{RUD;t} - i_{USD;t})$$

The ex post benefits associated with the buffer use of international reserves are determined by the degree to which the central bank hoards most of the reserves in times of plenty (i.e., high oil price, low sovereign spreads, and strong ruble), and sells most of reserves at rainy days (i.e., low oil price, high sovereign spreads, and weak ruble). The ultimate gain reported in equation (2) is larger the higher is the volatility of the sovereign spreads and of the real exchange rate during oil prices cycle, and the bolder and better timed are the interventions of the central bank. Other things being equal, higher $\Phi(IR_{RU;t_1...t_2})$ is associated with higher quality of the flow policies of a central bank, contributing to lower real exchange rate volatility during a commodity cycle.

Net present value of financial buffer stock services

The total net present value of the costs of the IR over time, denoted by $\Gamma(IR_{RU;t_1...t_2})$, adds to discounted flow service $\Phi(IR_{RU;t_1...t_2})$ the discounted opportunity costs of the average 'passive' stock of reserves:

$$(3) \qquad \Gamma(IR_{RU;t_1...t_2}) = \sum_{t_1}^{t_2} \frac{1}{(1+\rho)^t} (i_{RUD;t} - i_{USD;t})(\Delta IR_{RU,t} + IR_{RU,t-1}) \frac{E_{RU/\$,t}}{CPI_{RU,t}} =$$

$$\sum_{t_1}^{t_2} \frac{1}{(1+\rho)^t} (i_{RUD;t} - i_{USD;t}) IR_{RU,t} \frac{E_{RU/\$,t}}{CPI_{RU,t}} \quad .$$

This measure is the proper one in assess the costs and benefits of reducing the odds of a sudden stop crisis, the focus of Rodrik (2006).

Discount factors and estimation windows

We apply 2 alternatives of discount factors, $\rho = 0\%$ and $\rho = 0\%$. Our sample covers 2000Q1-2019Q1, subject to the availability of quarterly data the start date for each country may vary.[5] To gain further insight, we also report the cumulated buffer services of IR scaled by the average IR holdings: $\Gamma(IR_{RU;t}) / M(IR_{RU;t})$. Figure 2.1 provides the time patterns of the social costs and benefits of international reserves. The top panel reports the time path of the n.p.v. of social benefit of international reserve interventions, where buying reserves is a cost, selling is a benefit (equation 2). The bottom panel reports the time path of the n.p.v. of social costs of the stock of reserves [equation 3, $\Gamma(IR_{RU;t})$, and $\Gamma(IR_{RU;t}) / M(IR_{RU;t})$]. The top panel of Figure 2.1 indicates that during the period 2002-2019, the Russian Central Bank interventions added to a benefit of about 3 percent of the average external reserves (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). The bottom panel indicates that the total cost of average reserve position of Russia during that period was about 4 percent of its IR position.

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 macro prudential regulations and possibly external borrowing taxes scaling 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.[6] Political economy considerations suggest that the Russian central bank, operating with limited ability to impose macro prudential regulations on powerful insiders, may be credited for saving Russia from a much costlier exposure to sudden stops of the 1998 Russian crisis variety.

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[5] The starting times are: Brazil: 2006Q1, China: 2002Q2, India: 2002Q1, Indonesia: 2003Q2, Mexico: 2003Q1, Russia: 2001Q3, Turkey: 2000Q2, South Africa: 2000Q2).

[6] This point is reflected by the observation that the cumulative cost of Russian average reserves, $\Gamma(IR_{RU;t_1...t_2})$ added up to about 4 percent of the IR in 2019.

3. Comparative Analysis: BRICS+3

For our comparative analysis, we examine the largest emerging markets comprised of BRICS+3: Brazil, China, India, Indonesia, Mexico, Russia, South Africa, and Turkey; a group of emerging markets in the G20. Figures 1 and 2 include 8 panels, corresponding to the 8 countries in our sample. Focusing on the measures of IR financial buffer stock services $\phi(IR_{RU;t})$, $\Phi(IR_{RU;t_1 \dots t_2})$, $\Gamma(IR_{RU;t_1 \dots t_2})$, we estimate their variation (%) explained by IR adjustment (in USD), sovereign spreads (percentage points), and real exchange rates (local currency unit per US$ deflated by CPI) and provide the comparative charts illustrating the application of our framework in cross-country setup.

Using OLS estimation, Tables 1.1-1.3 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.

(4)

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

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

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

Figure 3 summarizes the estimation results across variables and countries. The top panel of each figure shows the IR services (sample average of dependent variables according to equations (1)-(3)) according to the specific measure and the bottom panel reports the coefficient estimates of reserve accumulation, sovereign spreads, and real exchange rates. The results indicates the following regularities during our sample period:

IR flow services (percent of GDP, equation 1): 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, equation 2): 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, equation 3): 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 2 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 (recall from equations (1) – (3) that the negative values of IR services correspond to selling international reserves). 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.

Counterfactual analysis: a case study of China and Russia

In this sub-section, we use a counterfactual analysis to provide an additional evidence based on the size and composition of reserves and real exchange rates. We study two IR policy changes: China’s 2010Q2 and Russia’s 2014Q2. China's reserves accumulation accelerated from about 15 percent of GDP in 2000, reached almost 50 percent of GDP in early 2010 and has since declined to below 25 percent by the end of the sample period. The counterfactual analysis focuses on the causal effect of this IR policy intervention on a time series of China's real exchange rate. Given the China's REER time series and a set of control REER time series (Brazil, India, Indonesia, Mexico, Russian, Turkey, and South Africa; using the BIS data [base year 2010]), we follow Brodersen et al. (2015), constructing a Bayesian structural time-series model to predict the counterfactual, i.e., how China's REER would have evolved after the 2010 China's IR intervention if the intervention had never occurred. In the case of Russia, we study its desire to change the composition of reserves from the US dollar to the Euro and Chinese Renminbi and what would have happened to the REER otherwise.

As this approach is non-experimental to causal inference, the assumption is that there is a set control time series (REER of other EMs) that were themselves not affected by the China's IR intervention. This is a rather strong assumption. If the REER of Brazil and other EMs were affected by China's IR policy of 2010, this analysis might under- or overestimate the true effect. The counterfactual analysis also assumes that the relationship between China's REER (treated) and other EMs' REER (controlled) time series during the pre-treatment period is stable throughout the post-treatment period. Subject to these specific priors the analysis performs posterior inference on the counterfactual, and returns a China's counterfactual REER. Appendix Figure A3 provides the time profile of REER and sovereign spreads of countries in our sample.

To estimate a causal effect, we begin by specifying 2002Q2-2010Q1 for training the model (pre-intervention period) and 2010Q2-2019Q1 period for computing a counterfactual prediction (post-intervention period). A top panel of Figure 4.1 plots China's real exchange rate series and counterfactuals based on the Bayesian structural time-series models, showing the data and a counterfactual prediction for the post-treatment period. The bottom panel shows the difference between observed China's REER data and counterfactual China's REER predictions; the pointwise causal effect, as estimated by the model.

A counterfactual prediction suggests that the deceleration of reserve hoarding policy has resulted in the appreciation of Chinese real exchange rate close to 20 percent in the decade that followed. Table 3 reports the average (across time) during the post-intervention period (2002Q2-2010Q1). The estimated average causal effect of China's IR policy intervention treatment was 19. This is because we observed an average value of 116 but would have expected an average value of only 98. The 90 percent posterior interval of the average effect is [15, 23]. Since this interval excludes 0, we find supportive evidence that the China's IR intervention had a causal effect on China's REER.[7]

For the case of Russia’s IR composition, we consider 2014Q2 [the year of Russia annexing Crimea] the beginning of a process inducing Russia to switch gradually the denomination of its reserves from the Dollar to the Euro and Chinese Renminbi. This is in line with Tett (2019), reporting that between July 2017 and July 2018, Russia cut the dollar proportion of its IR from 46.3% to 21%. Table 3

[7] Nevertheless, because our controls (other EMs' REER) might be affected by the China's intervention, the veracity of this analysis rests on whether the assumptions underlying this counterfactual exercise are justified. See Cheung, Chinn and Fujii (2009) for assessment of the challenges associated with measuring exchange rate misalignment.

and Figure 4.2 summarize our findings: 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]. This suggests the Russian's IR composition, shifting away from the dollar, induced the REER depreciation which would have been stronger otherwise.

4. Concluding Remarks

Our analysis focused on the recent international reserves management of eight large emerging-market economies. The sample period covers the commodity cycle from 2002-2007, including the oil-price rise and the drop of 2014, events that significantly impacted Emerging Markets' terms of trade. We provided a tractable analysis of the costs and benefits of a 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. We illustrated the benefits of exchange rate management for Russia, a prime example of a country with large exposure to commodity terms of trade volatility. Political economy considerations suggest that a central bank operating with limited ability to impose macro prudential regulations on powerful insiders may be credited for mitigating destabilizing transmission from volatility oil prices to the real exchange rate, possibly saving Russia from a costly sudden stop of the 1998 variety.

Issues left for future study include the rollover risks and liquidity needs of financial institutions, prudential regulations and active management of assets and liabilities mismatches aiming at reducing maturity, interest rate, and foreign exchange risks, and the availability of swap lines among the central banks.

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Table 1.1. IR flow services (eq.1, %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 1.2. IR cumulated flow services (eq.2, %IR)

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

	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 1.3. IR cumulated flow services + opportunity costs (eq.3, %IR)

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

	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 2. 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]: IR serv. eq.1	0.00	-0.27	-0.23	0.00	0.0	0.00	0.0	0.00
b[E/CPI]: IR serv. eq.2	-0.37	-0.76	-1.01	0.56	0.0	-0.83	0.0	0.52
b[E/CPI]: IR serv. eq.3	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);
Y1: $\phi\left(IR_{i;t}\right)$ IR flow services (eq.1, %GDP)
Y2: $\Phi(IR_{RU;t_1\ldots t_2})$ IR cumulated flow services (eq.2, %IR)
Y3: $\Gamma(IR_{RU;t_1\ldots t_2})$ IR cumulated flow services + opportunity costs (eq.3, %IR)
Share of commodity exports are from UNCTAD.

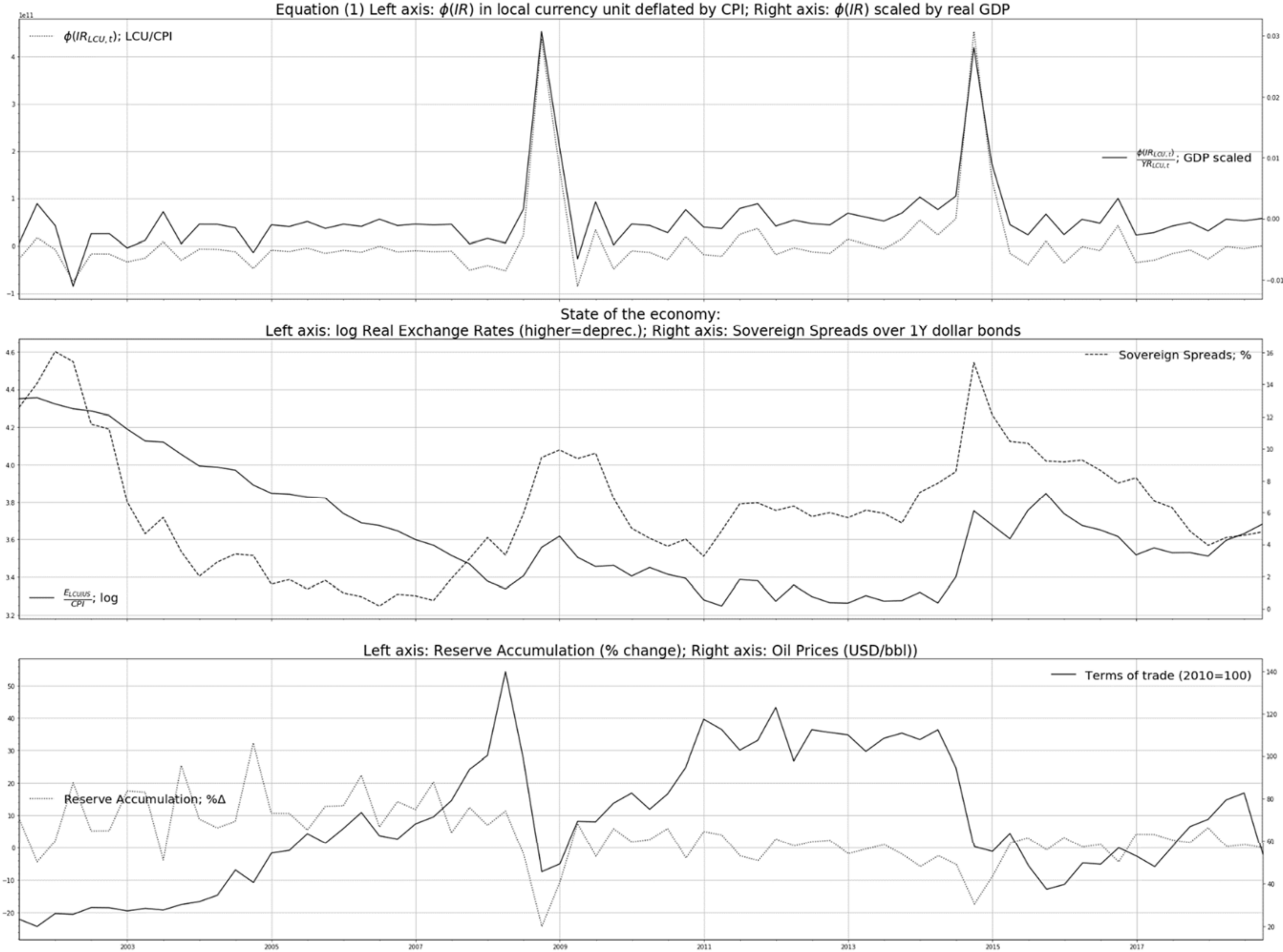
Table 3. Causal Impact of IR on REER: China and Russia

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.

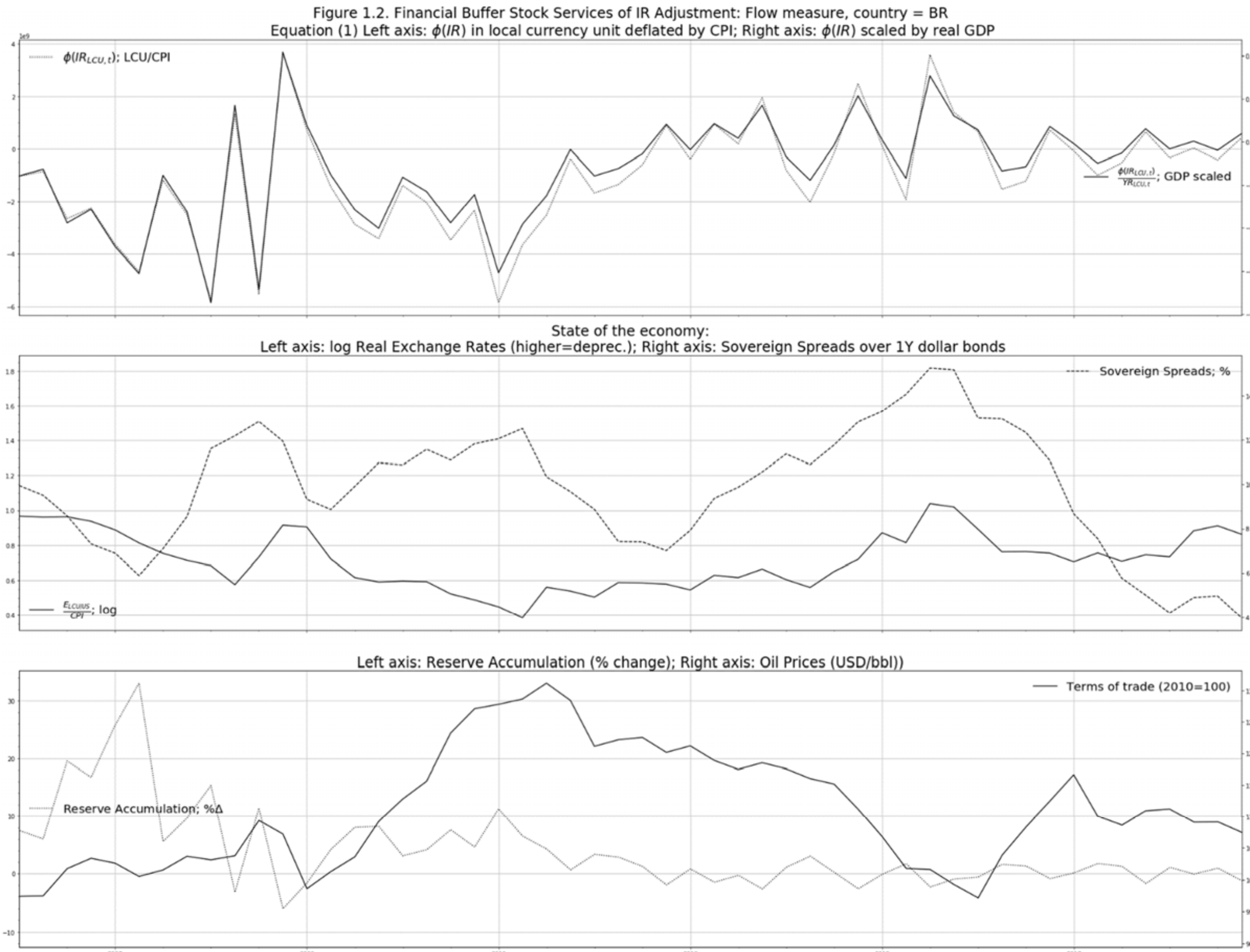
	China		Russia	
	Average	s.e.	Average	s.e.
Actual REER	116.0	0.0	83.0	0.0
Predicted REER	98.0	2.5	100.0	5.1
	Average	s.e.	Average	s.e.
Absolute eff.	19.0	2.5	-17.0	5.1

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

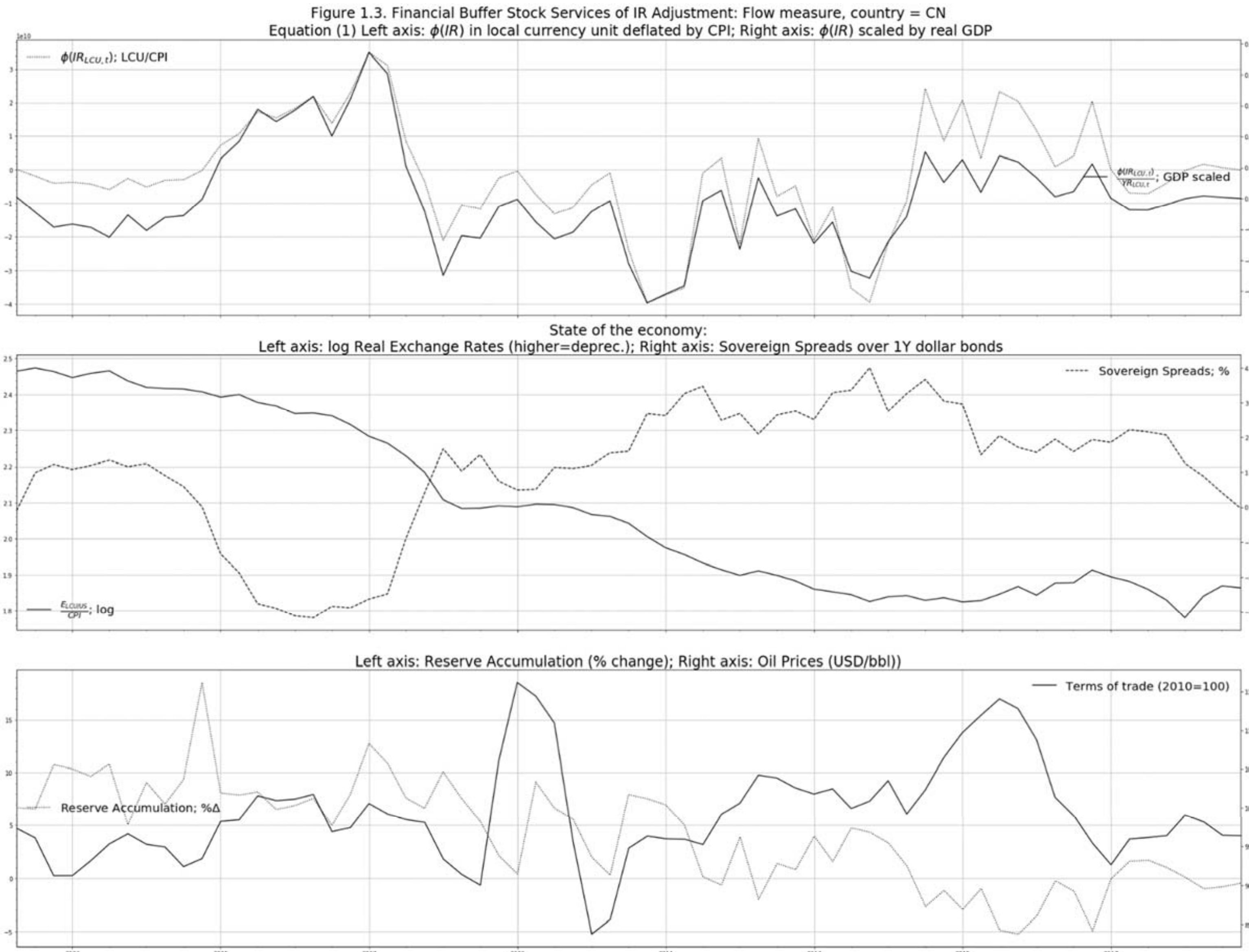
Figure 1.1. Financial Buffer Stock Services of IR Adjustment: Flow measure, country = RU
Equation (1) Left axis: $\phi(IR)$ in local currency unit deflated by CPI; Right axis: $\phi(IR)$ scaled by real GDP



Note: Based on equation (1) the top panel left scale in dotted .. curve is $\phi(IR)$ in real LCU (deflated by CPI), where CPI at year 2010 was 100.
The top panel right scale in solid curve is $\phi(IR)$ in terms of real GDP (YR), hence 0.02 is 2% of GDP in the corresponding year.
For RU, Brent Crude (USD/bbl) for the terms of trade.
The estimation uses sovereign spreads: over 1Y US Treasury (%). Reserve accumulation (% change): 100*[IR(t)-IR(t-1)]/IR(t-1); Source: Thomson Reuters Eikon API.



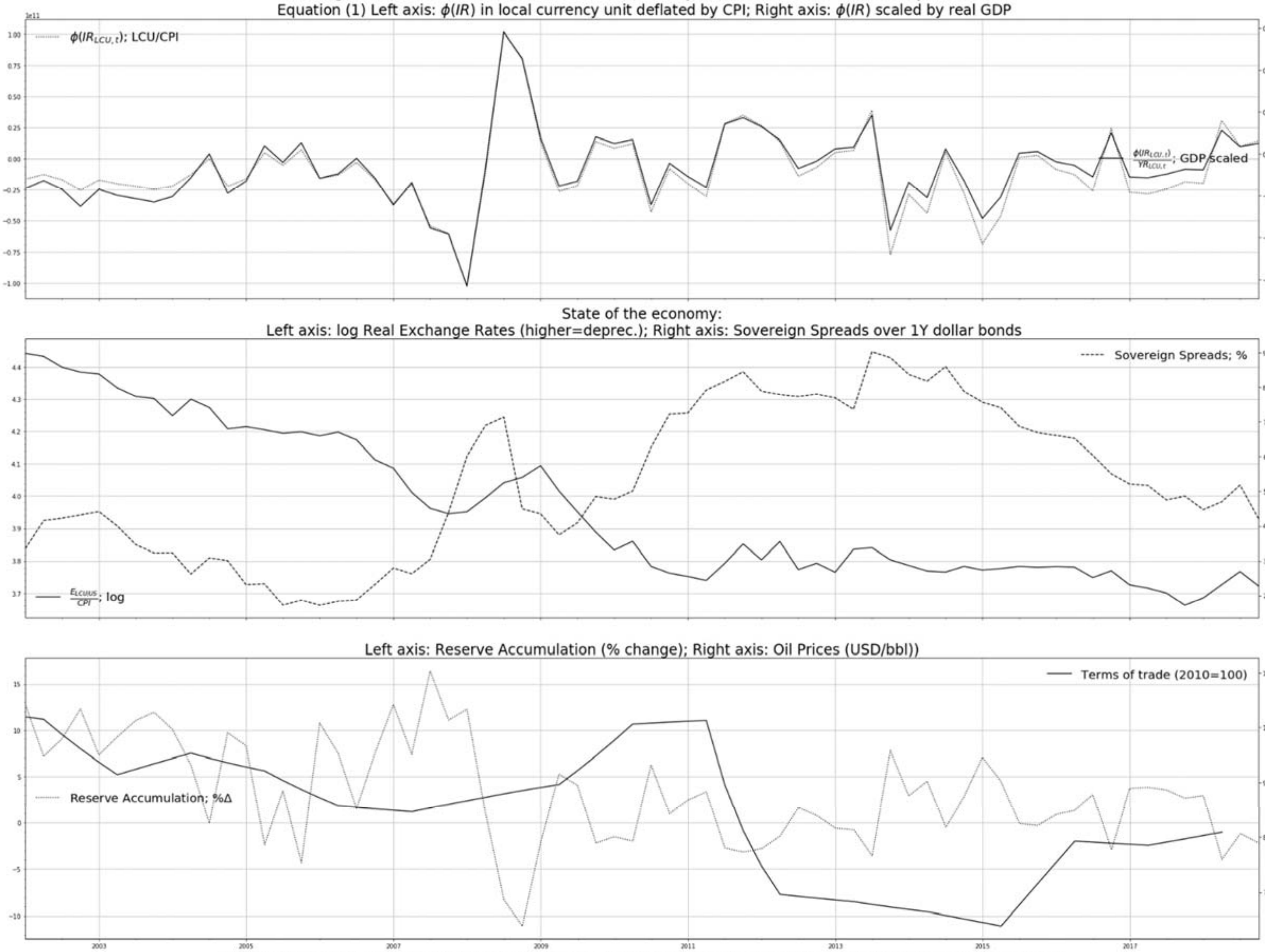
Note: Based on equation (1) the top panel left scale in dotted .. curve is $\phi(IR)$ in real LCU (deflated by CPI), where CPI at year 2010 was 100.
The top panel right scale in solid curve is $\phi(IR)$ in terms of real GDP (YR), hence 0.02 is 2% of GDP in the corresponding year.
For RU, Brent Crude (USD/bbl) for the terms of trade.
The estimation uses sovereign spreads: over 1Y US Treasury (%). Reserve accumulation (% change): 100*[IR(t)-IR(t-1)]/IR(t-1); Source: Thomson Reuters Eikon API.



Note: Based on equation (1) the top panel left scale in dotted .. curve is $\phi(IR)$ in real LCU (deflated by CPI), where CPI at year 2010 was 100.
The top panel right scale in solid curve is $\phi(IR)$ in terms of real GDP (YR), hence 0.02 is 2% of GDP in the corresponding year.
For RU, Brent Crude (USD/bbl) for the terms of trade.
The estimation uses sovereign spreads: over 1Y US Treasury (%). Reserve accumulation (% change): 100*[IR(t)-IR(t-1)]/IR(t-1); Source: Thomson Reuters Eikon API.

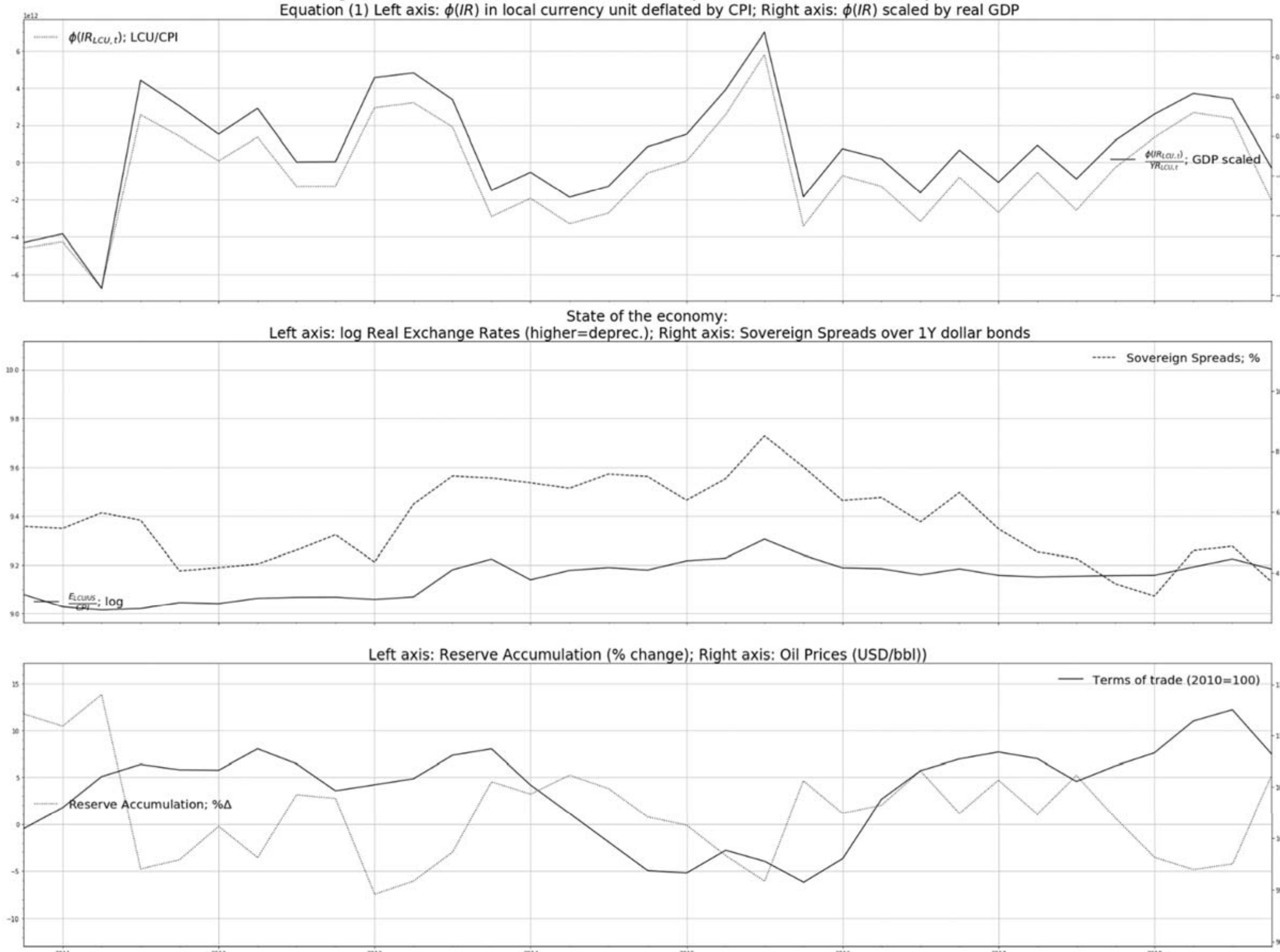
Figure 1.4. Financial Buffer Stock Services of IR Adjustment: Flow measure, country = IN

Equation (1) Left axis: $\phi(IR)$ in local currency unit deflated by CPI; Right axis: $\phi(IR)$ scaled by real GDP



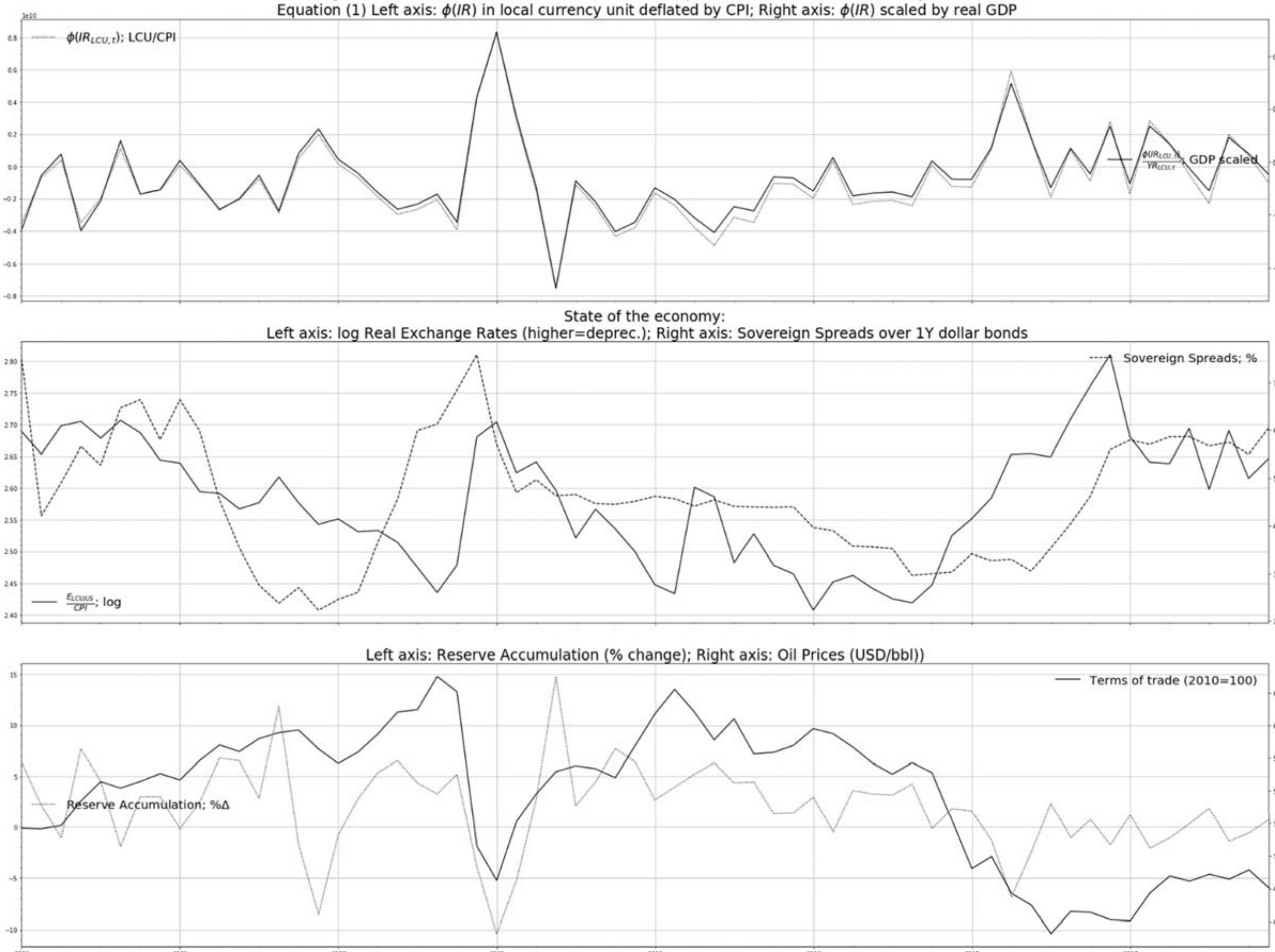
Note: Based on equation (1) the top panel left scale in dotted .. curve is $\phi(IR)$ in real LCU (deflated by CPI), where CPI at year 2010 was 100.
The top panel right scale in solid curve is $\phi(IR)$ in terms of real GDP (YR), hence 0.02 is 2% of GDP in the corresponding year.
For RU, Brent Crude (USD/bbl) for the terms of trade.
The estimation uses sovereign spreads: over 1Y US Treasury (%). Reserve accumulation (% change): 100*[IR(t)-IR(t-1)]/IR(t-1); Source: Thomson Reuters Eikon API.

Figure 1.5. Financial Buffer Stock Services of IR Adjustment: Flow measure, country = ID
Equation (1) Left axis: $\phi(IR)$ in local currency unit deflated by CPI; Right axis: $\phi(IR)$ scaled by real GDP



Note: Based on equation (1) the top panel left scale in dotted .. curve is $\phi(IR)$ in real LCU (deflated by CPI), where CPI at year 2010 was 100.
The top panel right scale in solid curve is $\phi(IR)$ in terms of real GDP (YR), hence 0.02 is 2% of GDP in the corresponding year.
For RU, Brent Crude (USD/bbl) for the terms of trade.
The estimation uses sovereign spreads: over 1Y US Treasury (%). Reserve accumulation (% change): 100*[IR(t)-IR(t-1)]/IR(t-1); Source: Thomson Reuters Eikon API.

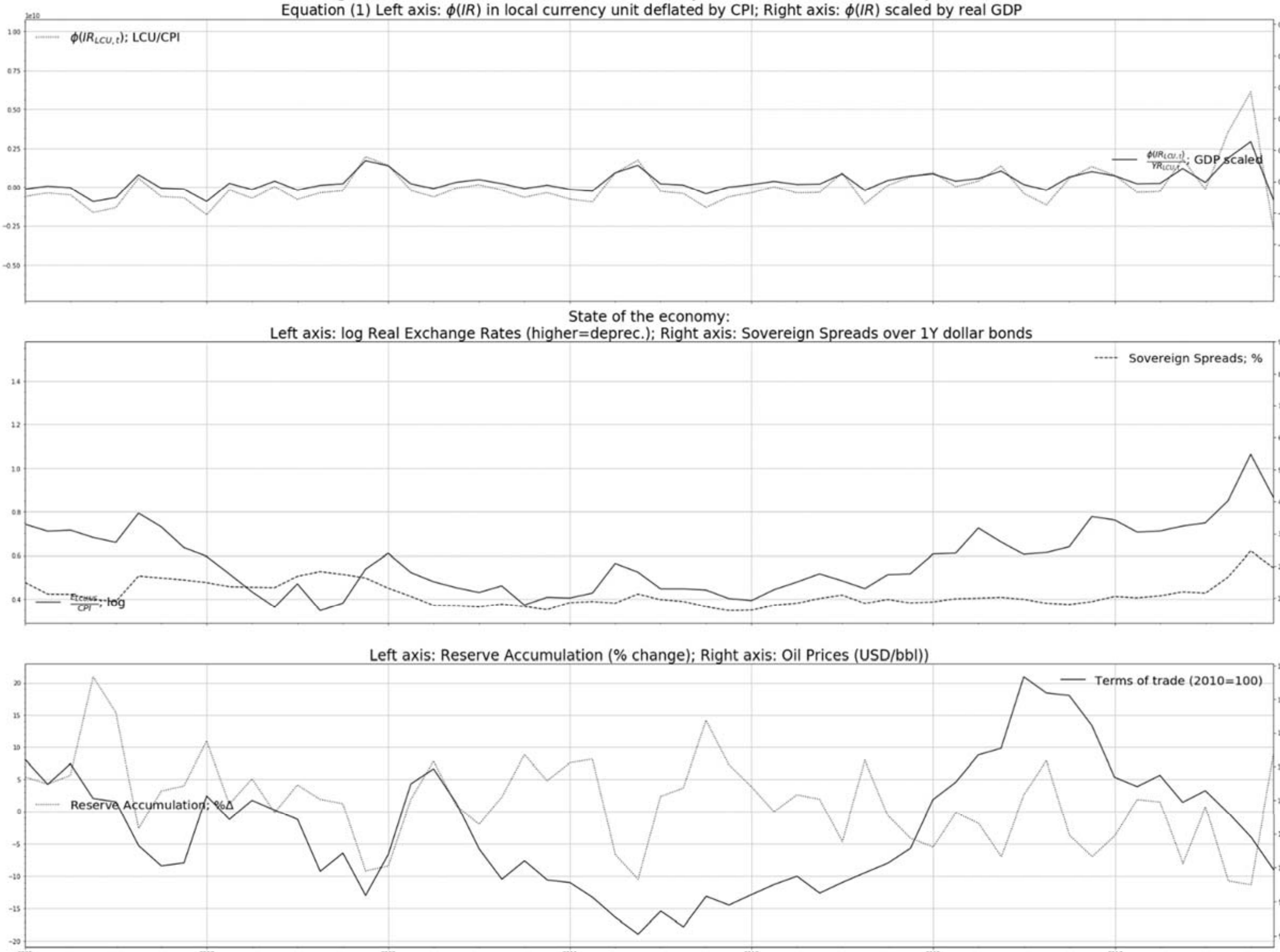
Figure 1.6. Financial Buffer Stock Services of IR Adjustment: Flow measure, country = MX
Equation (1) Left axis: $\phi(IR)$ in local currency unit deflated by CPI; Right axis: $\phi(IR)$ scaled by real GDP



Note: Based on equation (1) the top panel left scale in dotted .. curve is $\phi(IR)$ in real LCU (deflated by CPI), where CPI at year 2010 was 100.
The top panel right scale in solid curve is $\phi(IR)$ in terms of real GDP (YR), hence 0.02 is 2% of GDP in the corresponding year.
For RU, Brent Crude (USD/bbl) for the terms of trade.
The estimation uses sovereign spreads: over 1Y US Treasury (%). Reserve accumulation (% change): 100*[IR(t)-IR(t-1)]/IR(t-1); Source: Thomson Reuters Eikon API.

Figure 1.7. Financial Buffer Stock Services of IR Adjustment: Flow measure, country = TR

Equation (1) Left axis: $\phi(IR)$ in local currency unit deflated by CPI; Right axis: $\phi(IR)$ scaled by real GDP



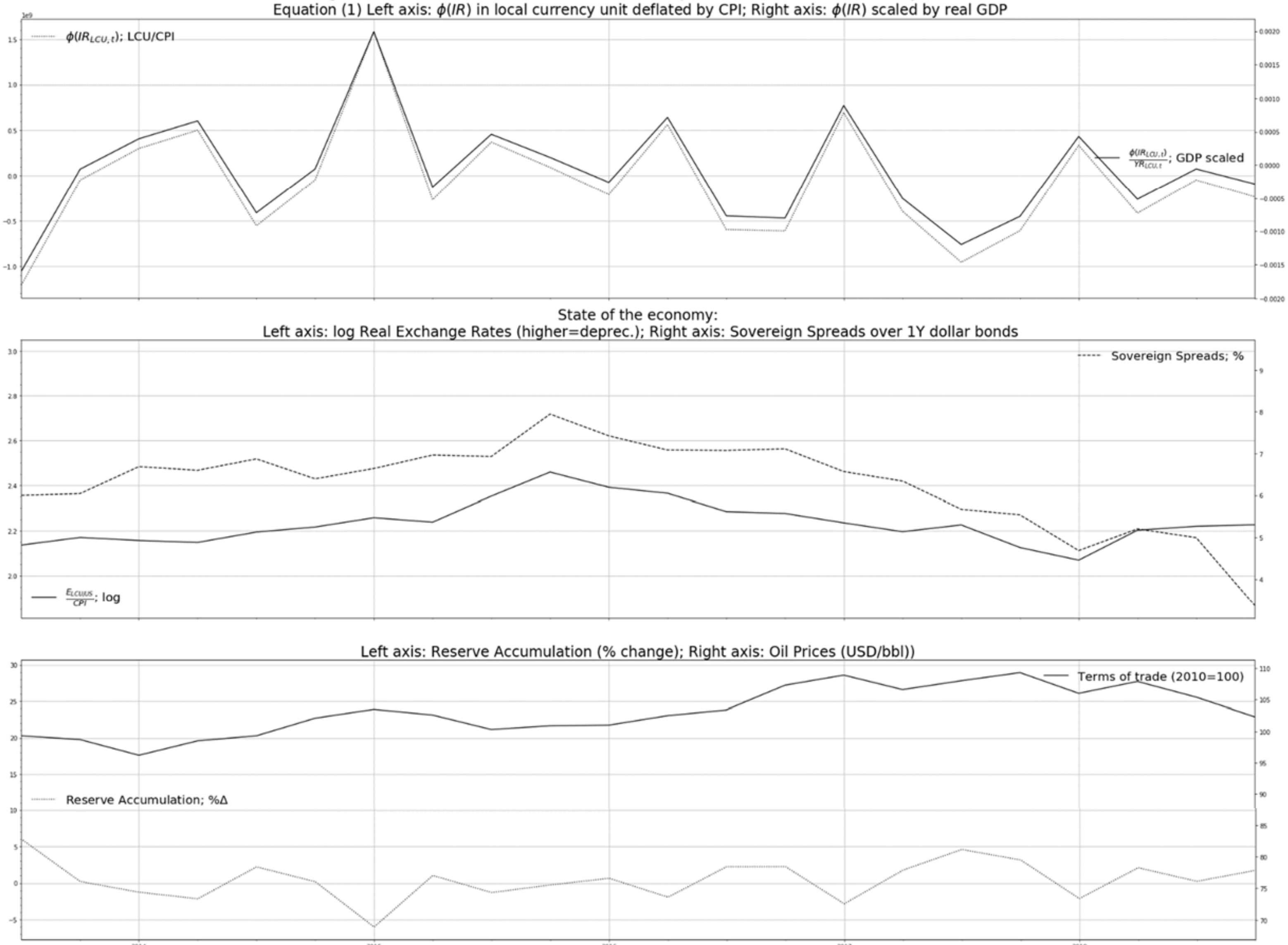
Note: Based on equation (1) the top panel left scale in dotted .. curve is $\phi(IR)$ in real LCU (deflated by CPI), where CPI at year 2010 was 100.

The top panel right scale in solid curve is $\phi(IR)$ in terms of real GDP (YR), hence 0.02 is 2% of GDP in the corresponding year.

For RU, Brent Crude (USD/bbl) for the terms of trade.

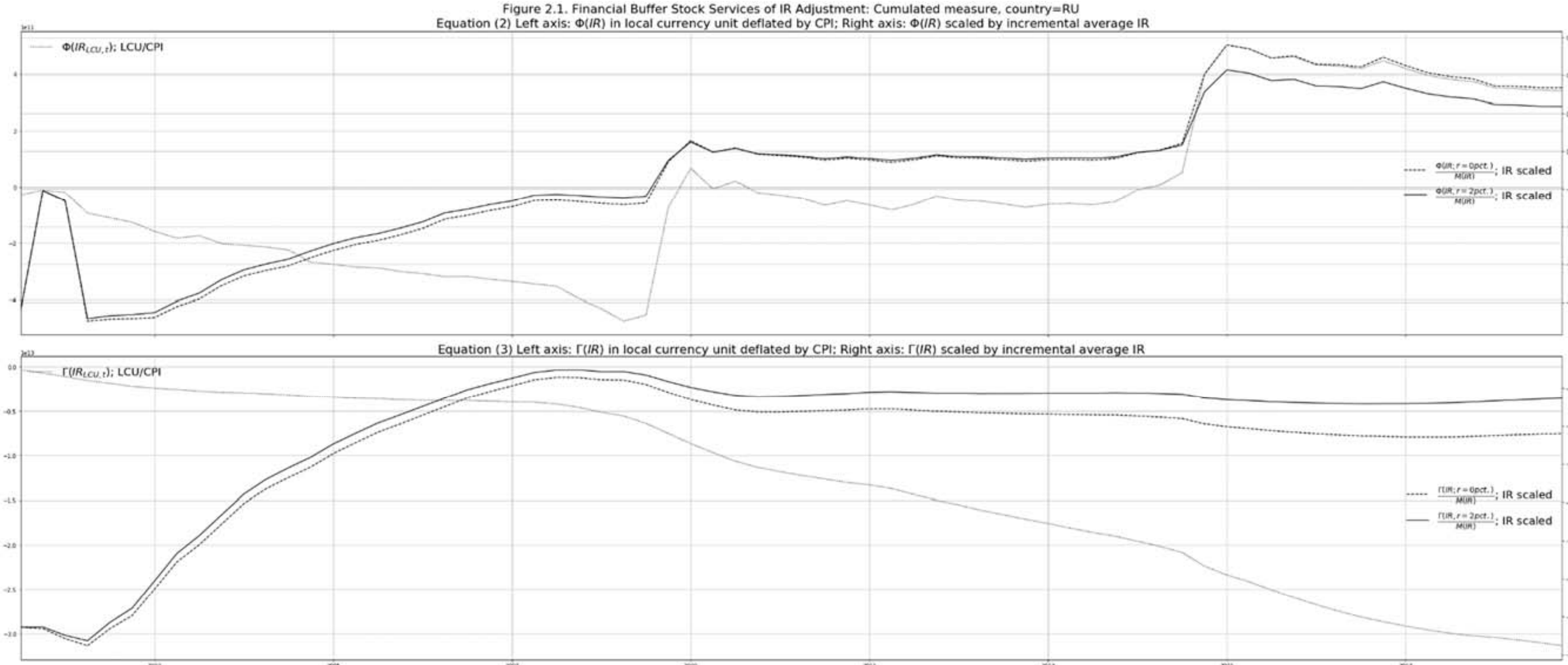
The estimation uses sovereign spreads: over 1Y US Treasury (%). Reserve accumulation (% change): 100*[IR(t)-IR(t-1)]/IR(t-1); Source: Thomson Reuters Eikon API.

Figure 1.8. Financial Buffer Stock Services of IR Adjustment: Flow measure, country = ZA
Equation (1) Left axis: $\phi(IR)$ in local currency unit deflated by CPI; Right axis: $\phi(IR)$ scaled by real GDP



Note: Based on equation (1) the top panel left scale in dotted .. curve is $\phi(IR)$ in real LCU (deflated by CPI), where CPI at year 2010 was 100.
The top panel right scale in solid curve is $\phi(IR)$ in terms of real GDP (YR), hence 0.02 is 2% of GDP in the corresponding year.
For RU, Brent Crude (USD/bbl) for the terms of trade.
The estimation uses sovereign spreads: over 1Y US Treasury (%). Reserve accumulation (% change): 100*[IR(t)-IR(t-1)]/IR(t-1); Source: Thomson Reuters Eikon API.

Figure 2.1. Financial Buffer Stock Services of IR Adjustment: Cumulated measure, country=RU

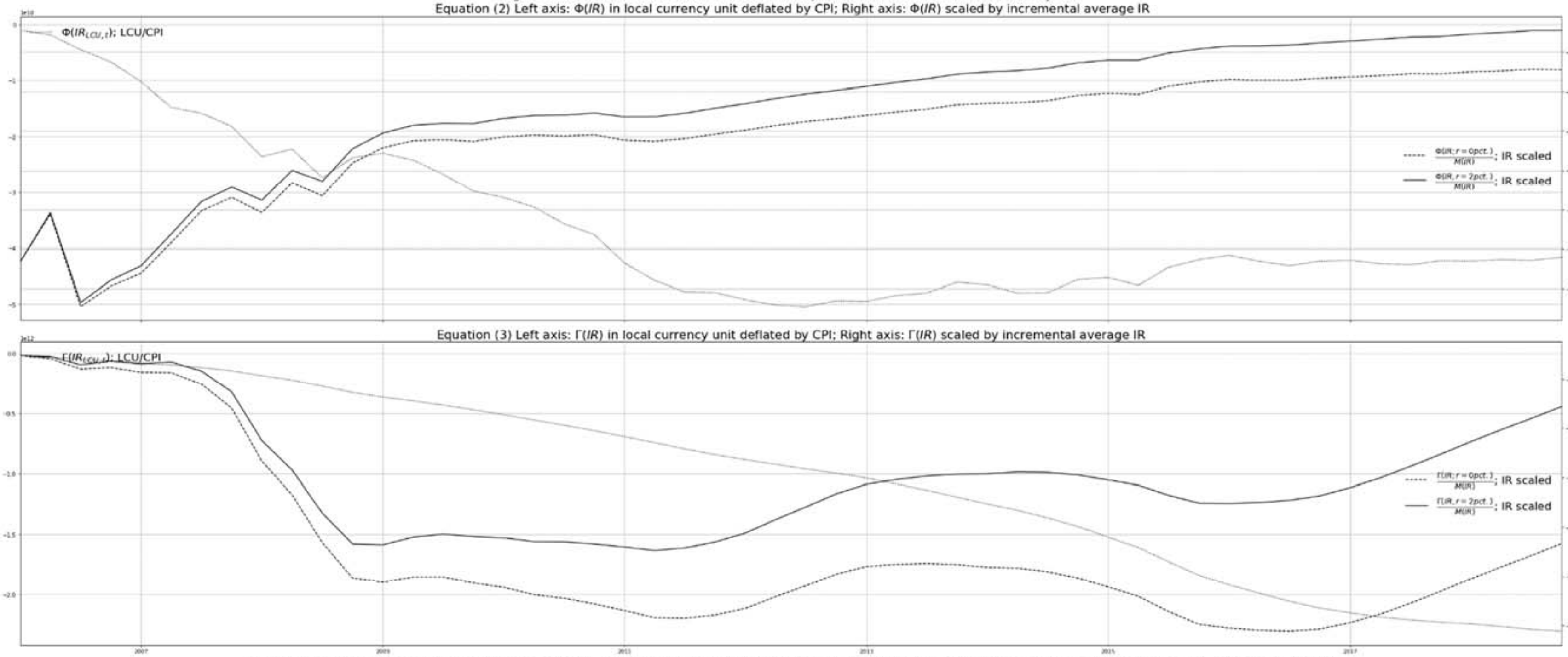


Note: Based on equation (2) the top panel left scale in dotted .. curve is $\Phi(IR)$ in real LCU (deflated by CPI, where CPI at year 2010 was 100), n.p.v. with discount rate of 2%, discounted to 2001Q3.
The top panel right scale in solid (dashed) curve is $\Phi(IR)$ in terms of the (incremental) average international reserves discounted n.p.v. with discount rate of 2% (0%), discounted from 2001Q3 to that specific year/quarter ; hence 0.03 is 3% of the discounted IR in the corresponding year.

Based on equation (3) the bottom panel left scale in dotted .. curve is $\Gamma(IR)$ in real LCU (deflated by CPI, where CPI at year 2010 was 100), n.p.v. with discount rate of 2%, discounted to 2001Q3.
The bottom panel right scale is $\Gamma(IR)$ in terms of the (incremental) average international reserves ($M(IR)$) from 2001Q3 to that specific year/quarter; hence 0.05 is 5% of the discounted IR in the corresponding year.
The solid curve corresponds to discount rate of 2%, and the dashed -- curve corresponds to n.p.v. with discount rate of 0%, discounted to 2001Q3.

The estimation uses sovereign spreads over 1Y US Treasury (%). Reserve accumulation: 100*[IR(t)-IR(t-1)]/IR(t-1); Source: Thomson Reuters Eikon API.

Figure 2.2. Financial Buffer Stock Services of IR Adjustment: Cumulated measure, country=BR
Equation (2) Left axis: Φ(*IR*) in local currency unit deflated by CPI; Right axis: Φ(*IR*) scaled by incremental average IR



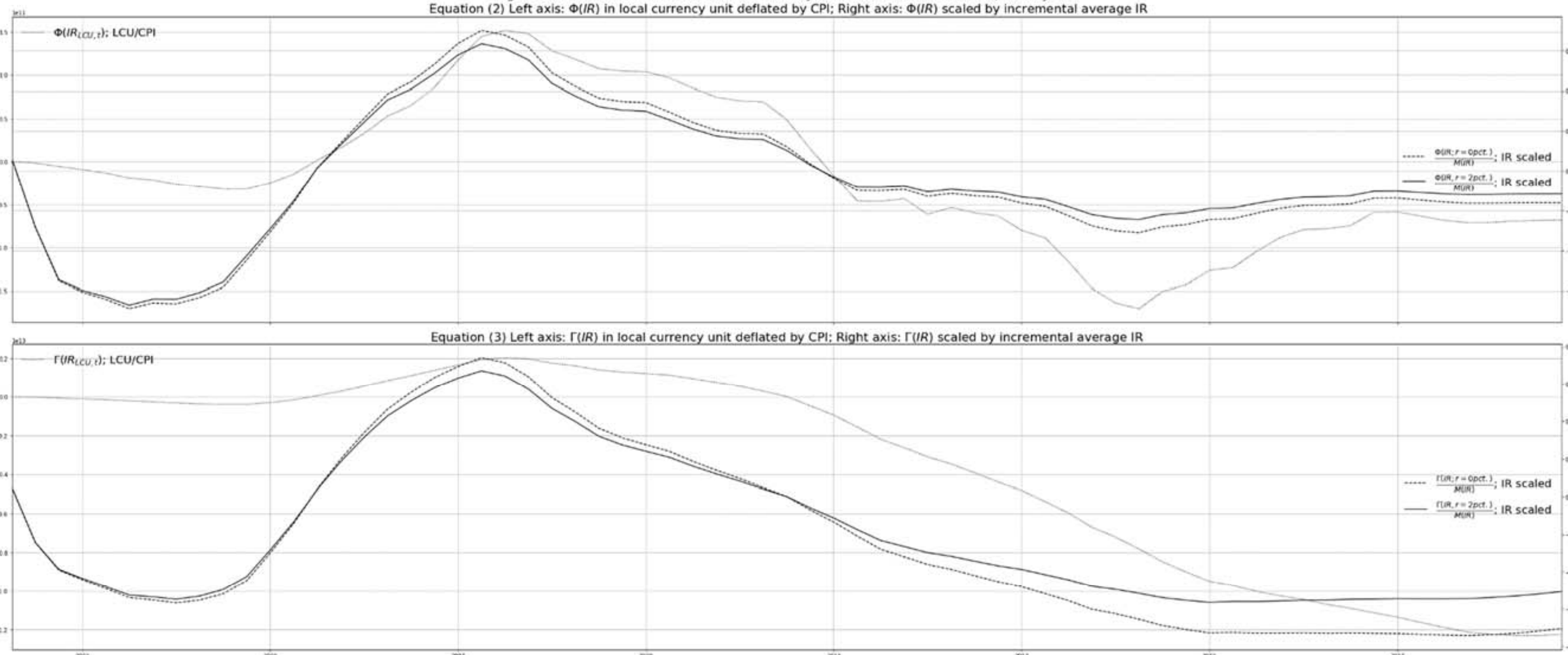
Note: Based on equation (2) the top panel left scale in dotted .. curve is Φ(*IR*) in real LCU (deflated by CPI, where CPI at year 2010 was 100), n.p.v. with discount rate of 2%, discounted to 2006Q1.
The top panel right scale in solid (dashed) curve is Φ(*IR*) in terms of the (incremental) average international reserves discounted n.p.v. with discount rate of 2% (0%), discounted from 2001Q3 to that specific year/quarter ; hence 0.03 is 3% of the discounted IR in the corresponding year.

Based on equation (3) the bottom panel left scale in dotted .. curve is Γ(*IR*) in real LCU (deflated by CPI, where CPI at year 2010 was 100), n.p.v. with discount rate of 2%, discounted to 2006Q1.
The bottom panel right scale is Γ(*IR*) in terms of the (incremental) average international reserves (*M*(*IR*)) from 2006Q1 to that specific year/quarter; hence 0.05 is 5% of the discounted IR in the corresponding year.
The solid curve corresponds to discount rate of 2%, and the dashed -- curve corresponds to n.p.v. with discount rate of 0%, discounted to 2006Q1.

The estimation uses sovereign spreads over 1Y US Treasury (%). Reserve accumulation: 100*[IR(t)-IR(t-1)]/IR(t-1); Source: Thomson Reuters Eikon API.

Figure 2.3. Financial Buffer Stock Services of IR Adjustment: Cumulated measure, country=CN

Equation (2) Left axis: Φ(IR) in local currency unit deflated by CPI; Right axis: Φ(IR) scaled by incremental average IR



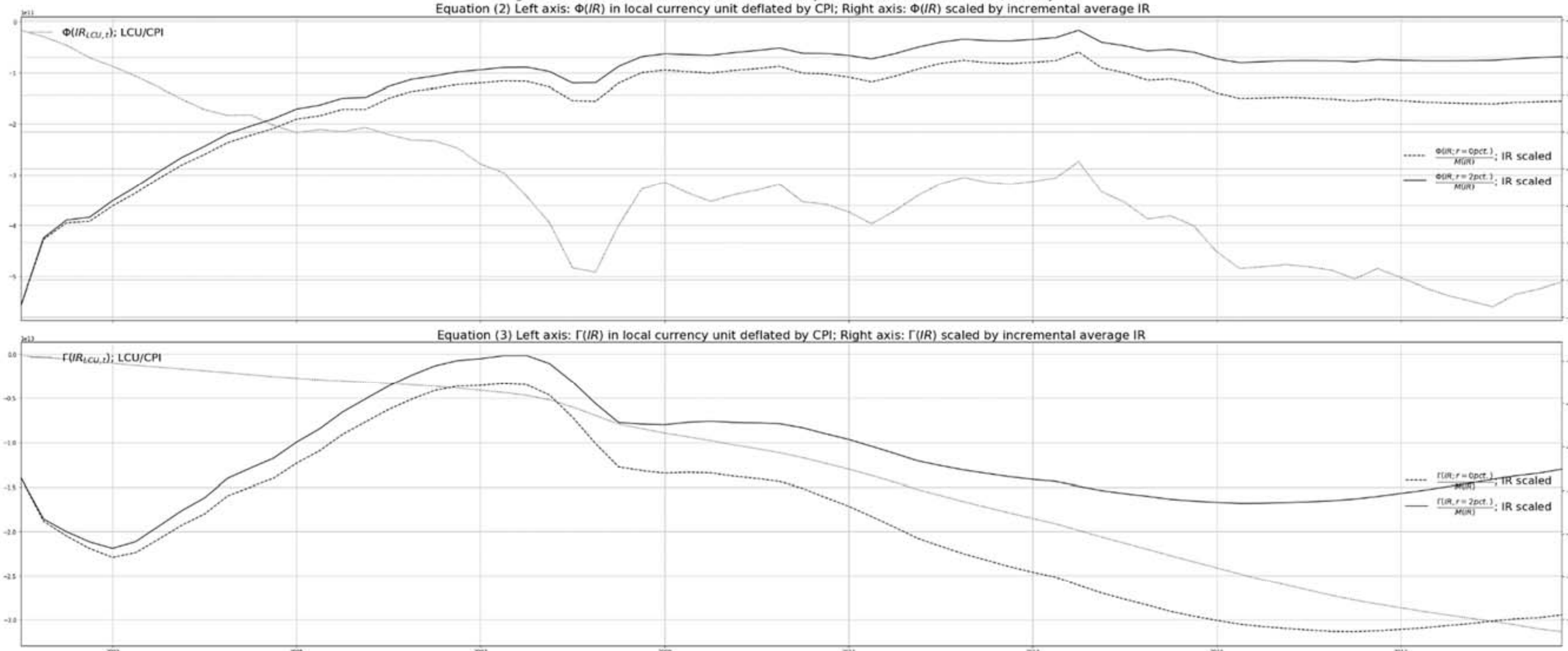
Note: Based on equation (2) the top panel left scale in dotted .. curve is Φ(IR) in real LCU (deflated by CPI, where CPI at year 2010 was 100), n.p.v. with discount rate of 2%, discounted to 2002Q2.
The top panel right scale in solid (dashed) curve is Φ(IR) in terms of the (incremental) average international reserves discounted n.p.v. with discount rate of 2% (0%), discounted from 2001Q3 to that specific year/quarter ; hence 0.03 is 3% of the discounted IR in the corresponding year.

Based on equation (3) the bottom panel left scale in dotted .. curve is Γ(IR) in real LCU (deflated by CPI, where CPI at year 2010 was 100), n.p.v. with discount rate of 2%, discounted to 2002Q2.
The bottom panel right scale is Γ(IR) in terms of the (incremental) average international reserves (M(IR)) from 2002Q2 to that specific year/quarter; hence 0.05 is 5% of the discounted IR in the corresponding year.
The solid curve corresponds to discount rate of 2%, and the dashed -- curve corresponds to n.p.v. with discount rate of 0%, discounted to 2002Q2.

The estimation uses sovereign spreads over 1Y US Treasury (%). Reserve accumulation: 100*[IR(t)-IR(t-1)]/IR(t-1); Source: Thomson Reuters Eikon API.

Figure 2.4. Financial Buffer Stock Services of IR Adjustment: Cumulated measure, country=IN

Equation (2) Left axis: Φ(*IR*) in local currency unit deflated by CPI; Right axis: Φ(*IR*) scaled by incremental average IR

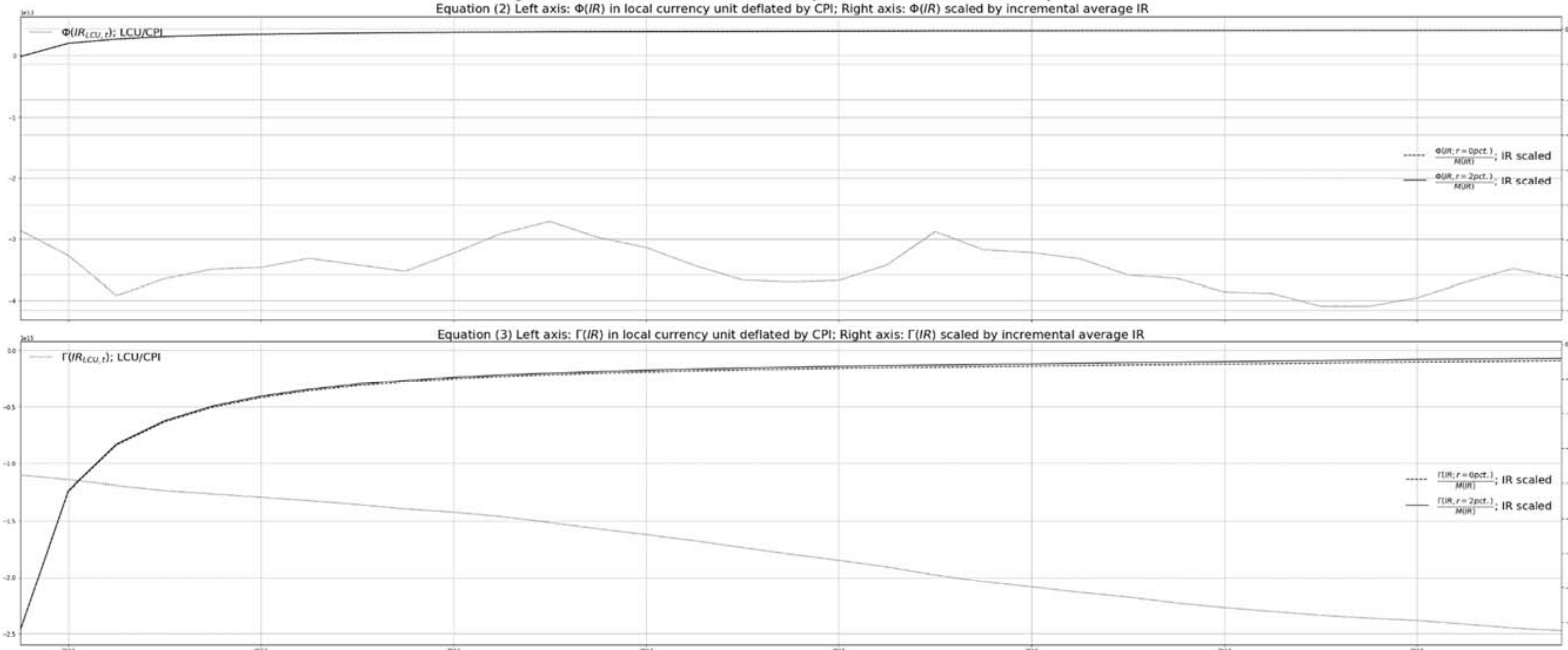


Note: Based on equation (2) the top panel left scale in dotted .. curve is Φ(*IR*) in real LCU (deflated by CPI, where CPI at year 2010 was 100), n.p.v. with discount rate of 2%, discounted to 2002Q1.
The top panel right scale in solid (dashed) curve is Φ(*IR*) in terms of the (incremental) average international reserves discounted n.p.v. with discount rate of 2% (0%), discounted from 2001Q3 to that specific year/quarter
; hence 0.03 is 3% of the discounted IR in the corresponding year.

Based on equation (3) the bottom panel left scale in dotted .. curve is Γ(*IR*) in real LCU (deflated by CPI, where CPI at year 2010 was 100), n.p.v. with discount rate of 2%, discounted to 2002Q1.
The bottom panel right scale is Γ(*IR*) in terms of the (incremental) average international reserves (*M*(*IR*)) from 2002Q1 to that specific year/quarter; hence 0.05 is 5% of the discounted IR in the corresponding year.
The solid curve corresponds to discount rate of 2%, and the dashed -- curve corresponds to n.p.v. with discount rate of 0%, discounted to 2002Q1.

The estimation uses sovereign spreads over 1Y US Treasury (%). Reserve accumulation: 100*[IR(t)-IR(t-1)]/IR(t-1); Source: Thomson Reuters Eikon API.

Figure 2.5. Financial Buffer Stock Services of IR Adjustment: Cumulated measure, country=ID
Equation (2) Left axis: $\Phi(IR)$ in local currency unit deflated by CPI; Right axis: $\Phi(IR)$ scaled by incremental average IR

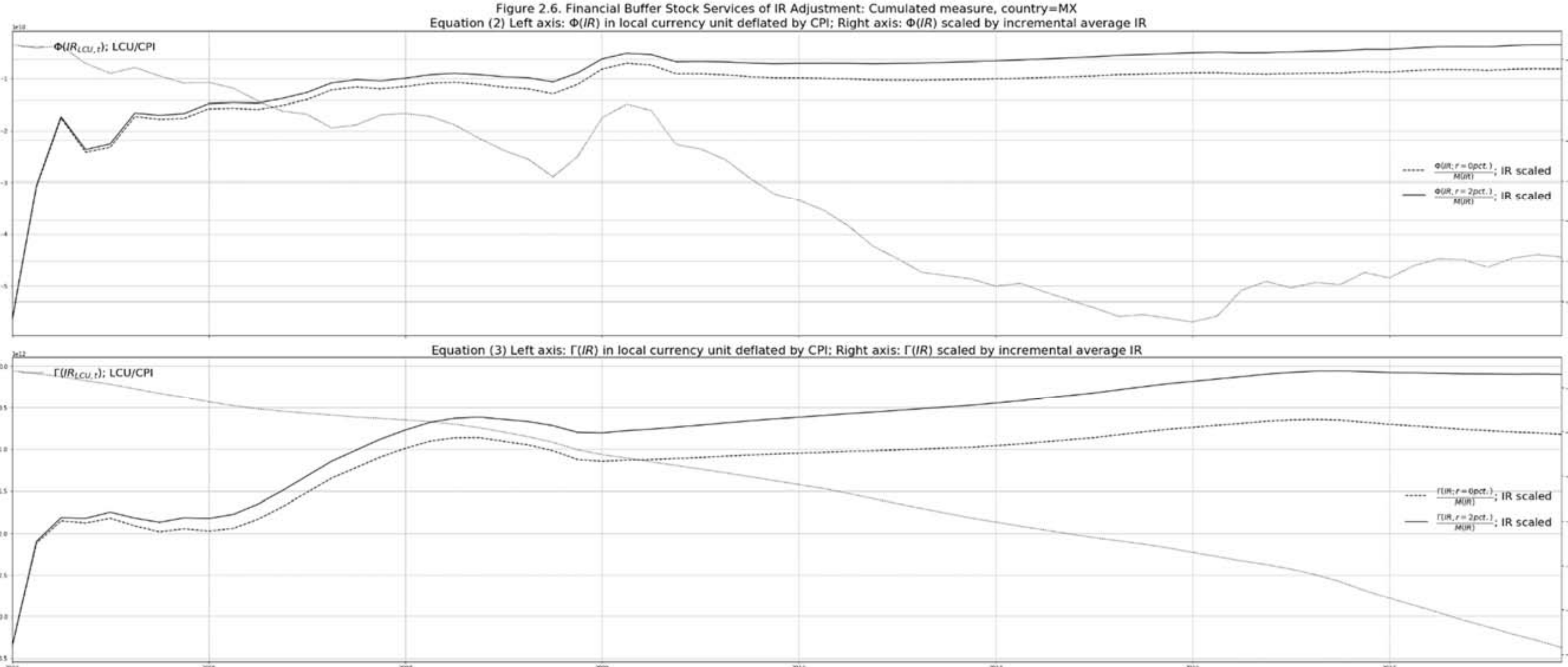


Note: Based on equation (2) the top panel left scale in dotted .. curve is $\Phi(IR)$ in real LCU (deflated by CPI, where CPI at year 2010 was 100), n.p.v. with discount rate of 2%, discounted to 2010Q4.
The top panel right scale in solid (dashed) curve is $\Phi(IR)$ in terms of the (incremental) average international reserves discounted n.p.v. with discount rate of 2% (0%), discounted from 2001Q3 to that specific year/quarter ; hence 0.03 is 3% of the discounted IR in the corresponding year.

Based on equation (3) the bottom panel left scale in dotted .. curve is $\Gamma(IR)$ in real LCU (deflated by CPI, where CPI at year 2010 was 100), n.p.v. with discount rate of 2%, discounted to 2010Q4.
The bottom panel right scale is $\Gamma(IR)$ in terms of the (incremental) average international reserves ($M(IR)$) from 2010Q4 to that specific year/quarter; hence 0.05 is 5% of the discounted IR in the corresponding year.
The solid curve corresponds to discount rate of 2%, and the dashed -- curve corresponds to n.p.v. with discount rate of 0%, discounted to 2010Q4.

The estimation uses sovereign spreads over 1Y US Treasury (%). Reserve accumulation: 100*[IR(t)-IR(t-1)]/IR(t-1); Source: Thomson Reuters Eikon API.

Figure 2.6. Financial Buffer Stock Services of IR Adjustment: Cumulated measure, country=MX

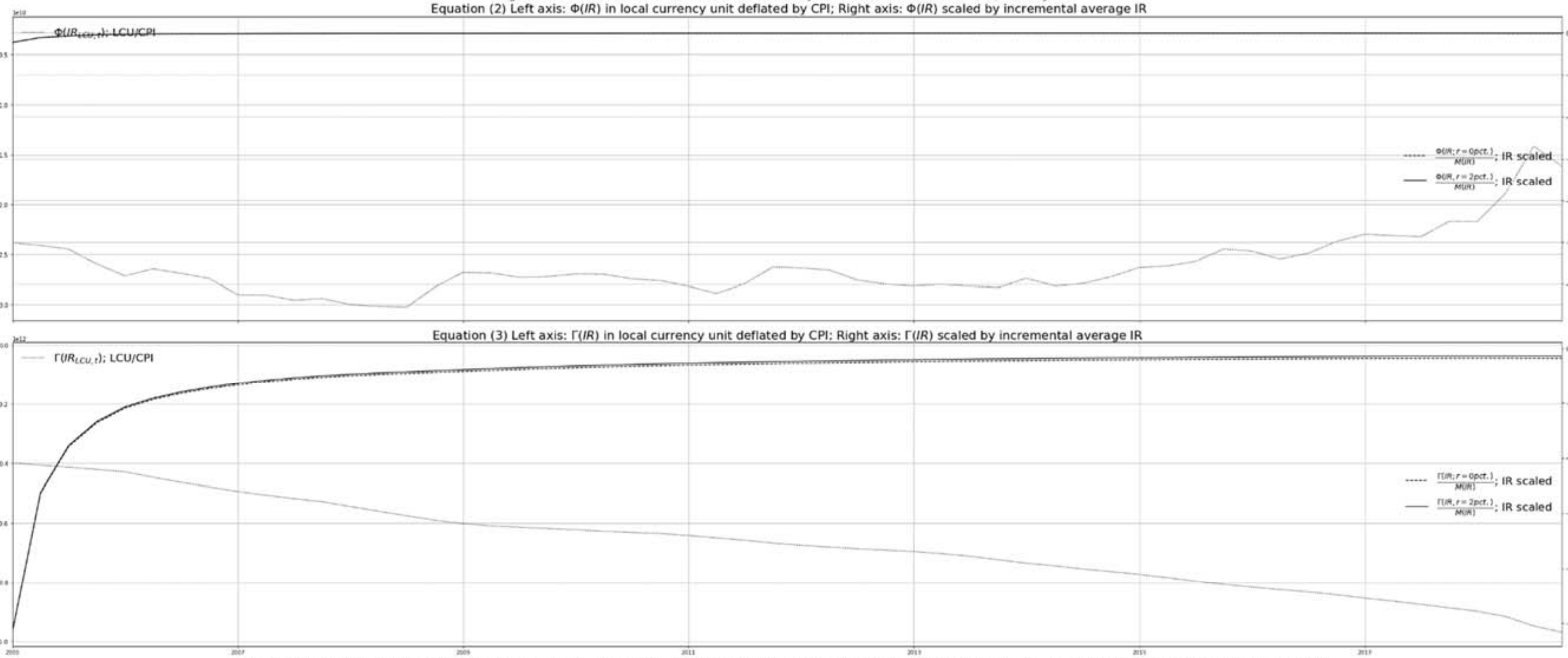


Note: Based on equation (2) the top panel left scale in dotted .. curve is Φ(*IR*) in real LCU (deflated by CPI, where CPI at year 2010 was 100), n.p.v. with discount rate of 2%, discounted to 2003Q1.
The top panel right scale in solid (dashed) curve is Φ(*IR*) in terms of the (incremental) average international reserves discounted n.p.v. with discount rate of 2% (0%), discounted from 2001Q3 to that specific year/quarter ; hence 0.03 is 3% of the discounted IR in the corresponding year.

Based on equation (3) the bottom panel left scale in dotted .. curve is Γ(*IR*) in real LCU (deflated by CPI, where CPI at year 2010 was 100), n.p.v. with discount rate of 2%, discounted to 2003Q1.
The bottom panel right scale is Γ(*IR*) in terms of the (incremental) average international reserves (*M*(*IR*)) from 2003Q1 to that specific year/quarter; hence 0.05 is 5% of the discounted IR in the corresponding year.
The solid curve corresponds to discount rate of 2%, and the dashed -- curve corresponds to n.p.v. with discount rate of 0%, discounted to 2003Q1.

The estimation uses sovereign spreads over 1Y US Treasury (%). Reserve accumulation: 100*[IR(t)-IR(t-1)]/IR(t-1); Source: Thomson Reuters Eikon API.

Figure 2.7. Financial Buffer Stock Services of IR Adjustment: Cumulated measure, country=TR
Equation (2) Left axis: Φ(*IR*) in local currency unit deflated by CPI; Right axis: Φ(*IR*) scaled by incremental average IR

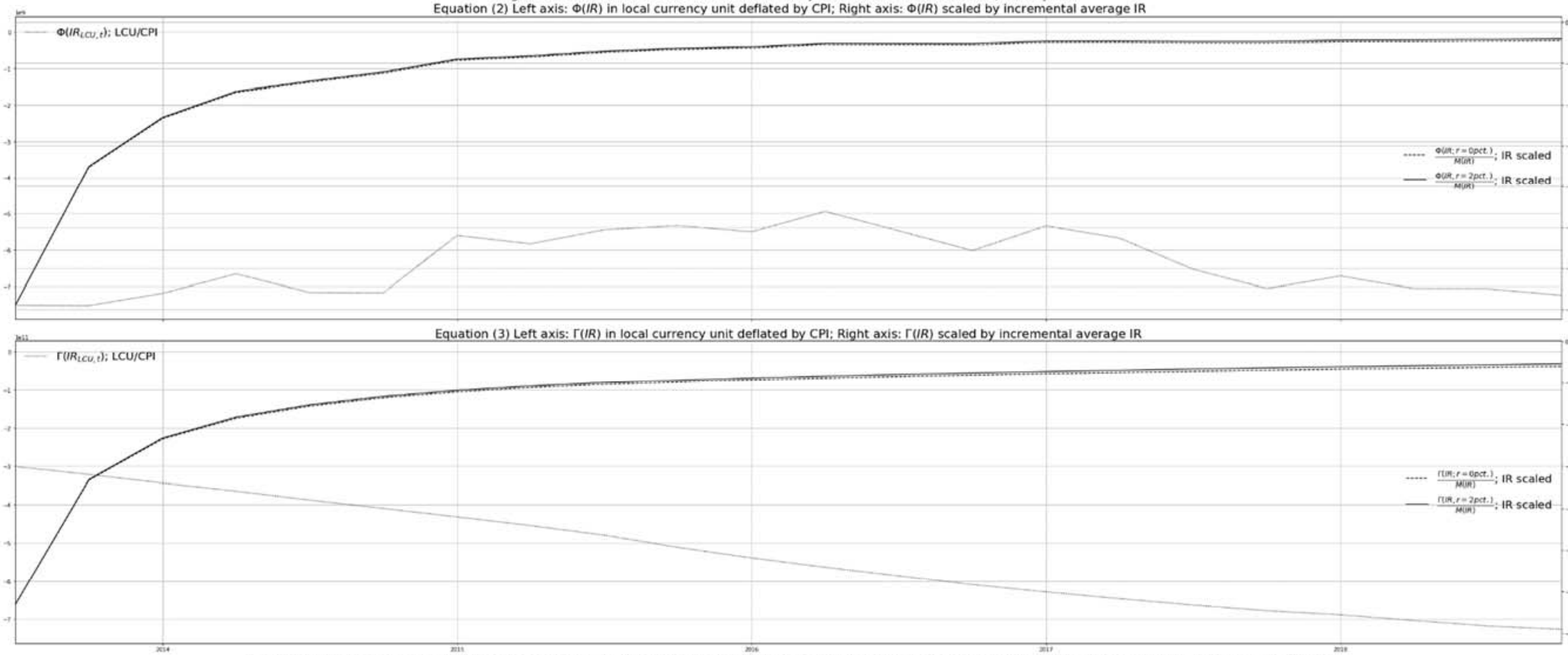


Note: Based on equation (2) the top panel left scale in dotted .. curve is Φ(*IR*) in real LCU (deflated by CPI, where CPI at year 2010 was 100), n.p.v. with discount rate of 2%, discounted to 2005Q1.
The top panel right scale in solid (dashed) curve is Φ(*IR*) in terms of the (incremental) average international reserves discounted n.p.v. with discount rate of 2% (0%), discounted from 2001Q3 to that specific year/quarter ; hence 0.03 is 3% of the discounted IR in the corresponding year.

Based on equation (3) the bottom panel left scale in dotted .. curve is Γ(*IR*) in real LCU (deflated by CPI, where CPI at year 2010 was 100), n.p.v. with discount rate of 2%, discounted to 2005Q1.
The bottom panel right scale is Γ(*IR*) in terms of the (incremental) average international reserves (*M*(*IR*)) from 2005Q1 to that specific year/quarter; hence 0.05 is 5% of the discounted IR in the corresponding year.
The solid curve corresponds to discount rate of 2%, and the dashed -- curve corresponds to n.p.v. with discount rate of 0%, discounted to 2005Q1.

The estimation uses sovereign spreads over 1Y US Treasury (%). Reserve accumulation: 100*[IR(t)-IR(t-1)]/IR(t-1); Source: Thomson Reuters Eikon API.

Figure 2.8. Financial Buffer Stock Services of IR Adjustment: Cumulated measure, country=ZA
Equation (2) Left axis: $\Phi(IR)$ in local currency unit deflated by CPI; Right axis: $\Phi(IR)$ scaled by incremental average IR



Note: Based on equation (2) the top panel left scale in dotted .. curve is $\Phi(IR)$ in real LCU (deflated by CPI, where CPI at year 2010 was 100), n.p.v. with discount rate of 2%, discounted to 2013Q3.
The top panel right scale in solid (dashed) curve is $\Phi(IR)$ in terms of the (incremental) average international reserves discounted n.p.v. with discount rate of 2% (0%), discounted from 2001Q3 to that specific year/quarter ; hence 0.03 is 3% of the discounted IR in the corresponding year.

Based on equation (3) the bottom panel left scale in dotted .. curve is $\Gamma(IR)$ in real LCU (deflated by CPI, where CPI at year 2010 was 100), n.p.v. with discount rate of 2%, discounted to 2013Q3.
The bottom panel right scale is $\Gamma(IR)$ in terms of the (incremental) average international reserves ($M(IR)$) from 2013Q3 to that specific year/quarter; hence 0.05 is 5% of the discounted IR in the corresponding year.
The solid curve corresponds to discount rate of 2%, and the dashed -- curve corresponds to n.p.v. with discount rate of 0%, discounted to 2013Q3.

The estimation uses sovereign spreads over 1Y US Treasury (%). Reserve accumulation: 100*[IR(t)-IR(t-1)]/IR(t-1); Source: Thomson Reuters Eikon API.

Figure 3.a.1. IR flow services (eq.1, %GDP) of BRIC+4
(Dependent variable of Table 1)

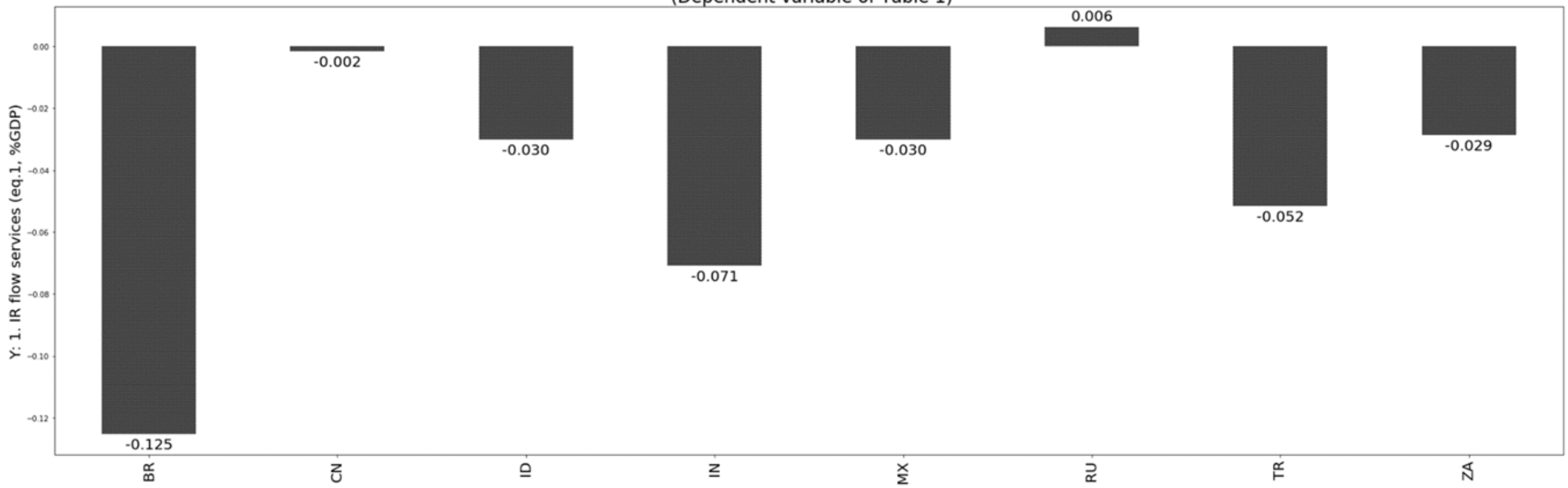


Figure 3.b.1. IR flow services (eq.1, %GDP) = $f(IR.accu.,Sov.sprd.,E/CPI)$
OLS coefficients of IR accumulation, sovereign spreads, and real exchange rates (higher=deprec.); all variables are standardized, ($\mu = 0, \delta = 1$)

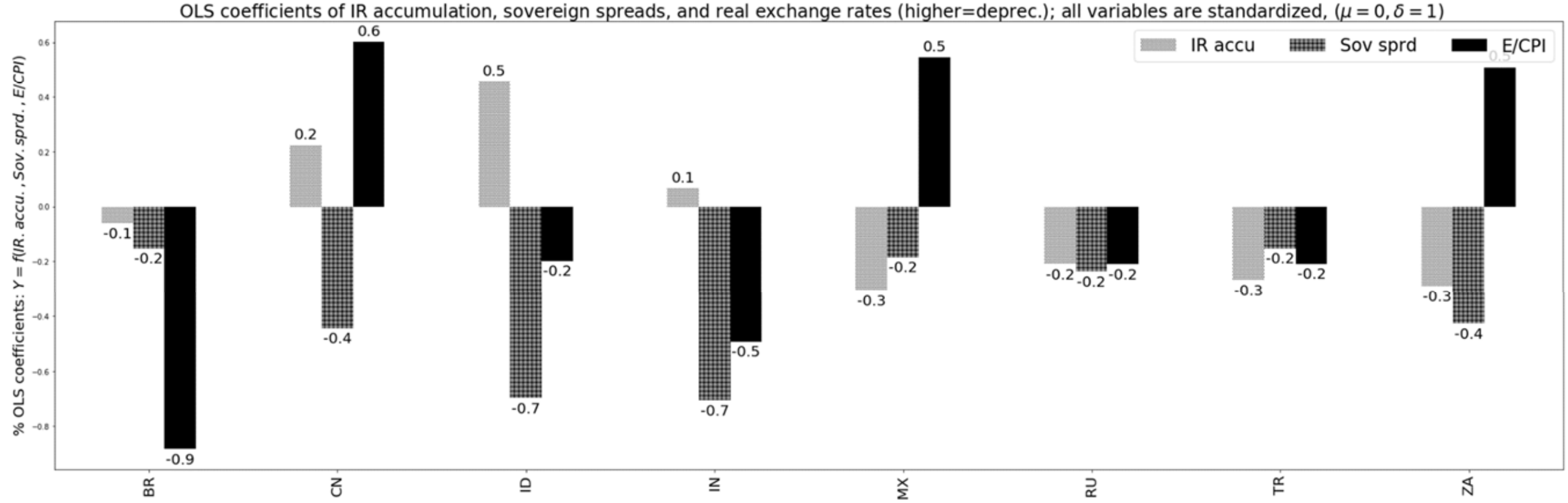


Figure 3.a.2. IR cumulated flow services (eq.2, %IR) of BRIC+4
(Dependent variable of Table 1)

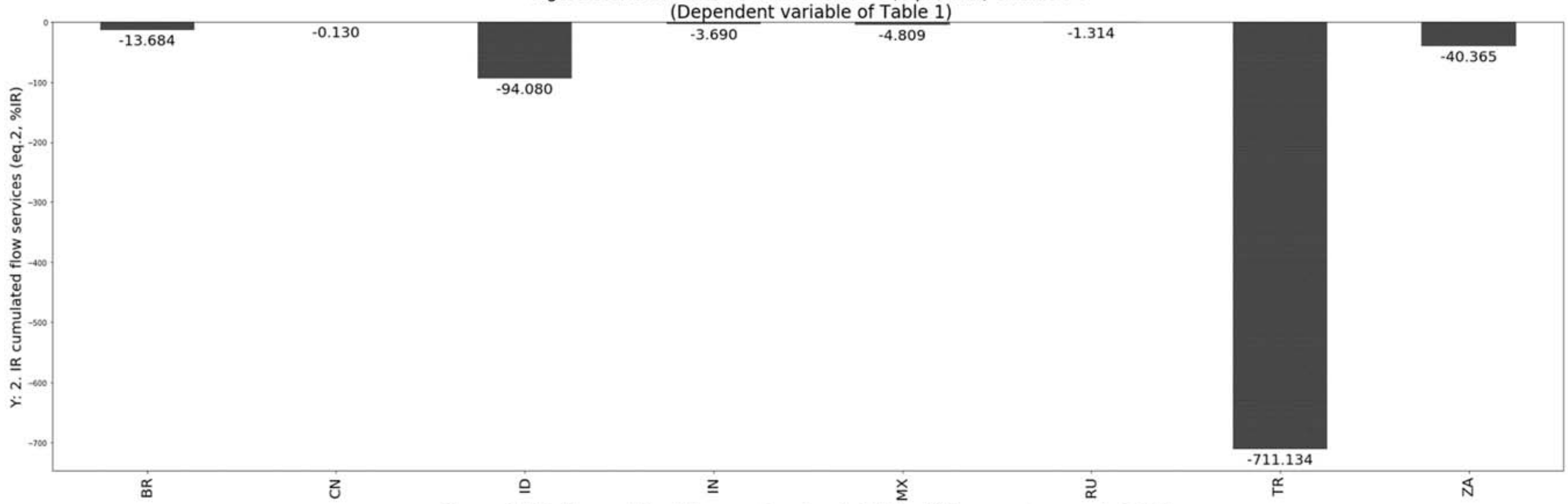


Figure 3.b.2. IR cumulated flow services (eq.2, %IR) = $f(IR.\,accu., Sov.\,sprd., E/CPI)$
OLS coefficients of IR accumulation, sovereign spreads, and real exchange rates (higher=deprec.); all variables are standardized, ($\mu = 0, \delta = 1$)

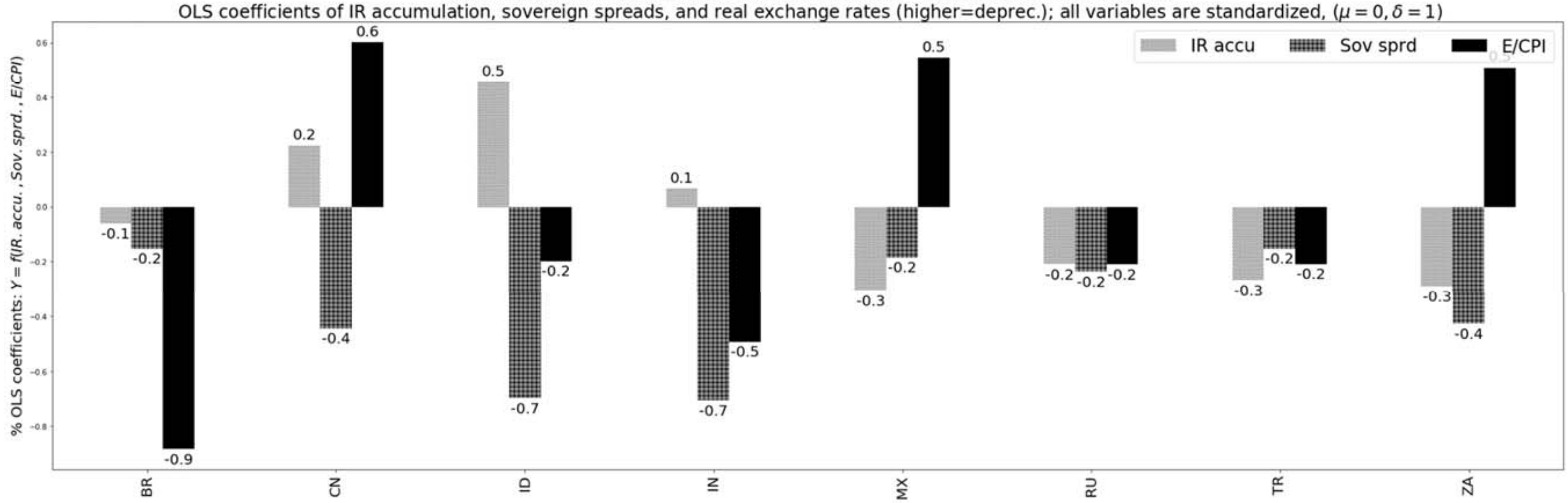


Figure 3.a.3. IR cumulated flow services + opportunity costs (eq.3, %IR) of BRIC+4
(Dependent variable of Table 1)

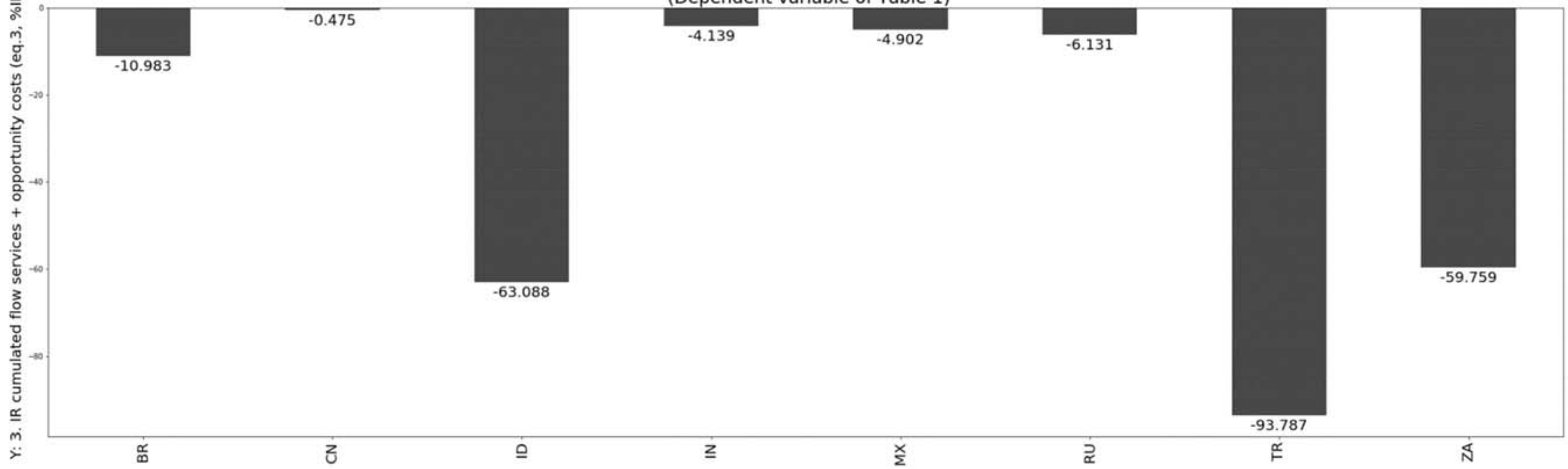


Figure 3.b.3. IR cumulated flow services + opportunity costs (eq.3, %IR) = $f(IR.accu., Sov.sprd., E/CPI)$
OLS coefficients of IR accumulation, sovereign spreads, and real exchange rates (higher=deprec.); all variables are standardized, ($\mu = 0, \delta = 1$)

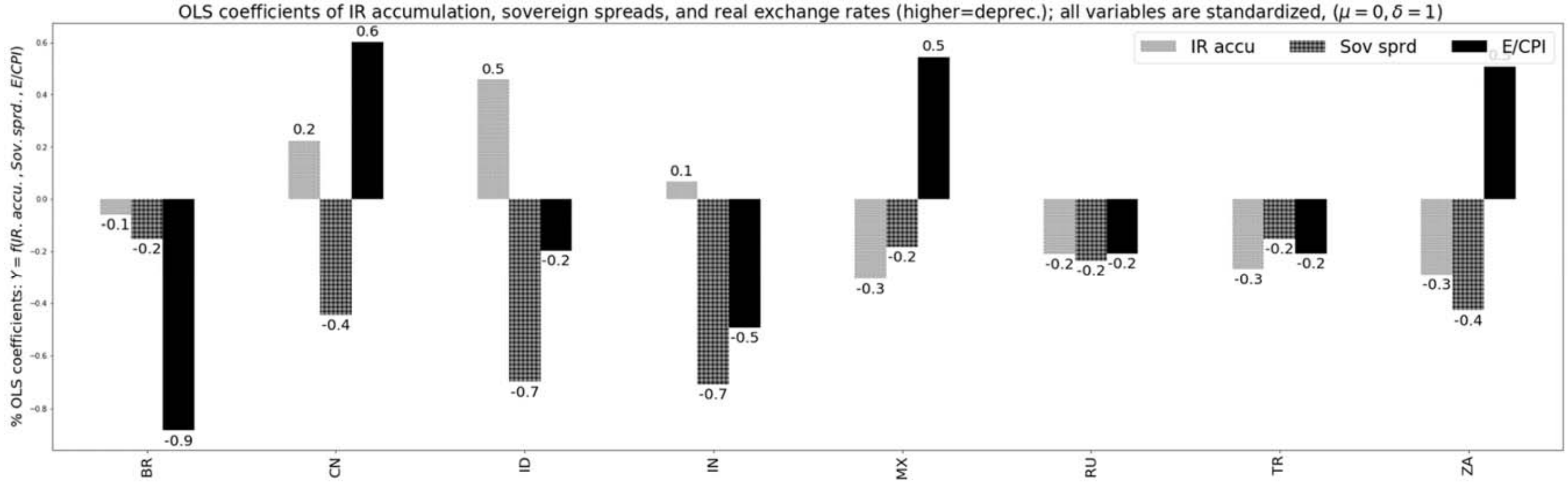
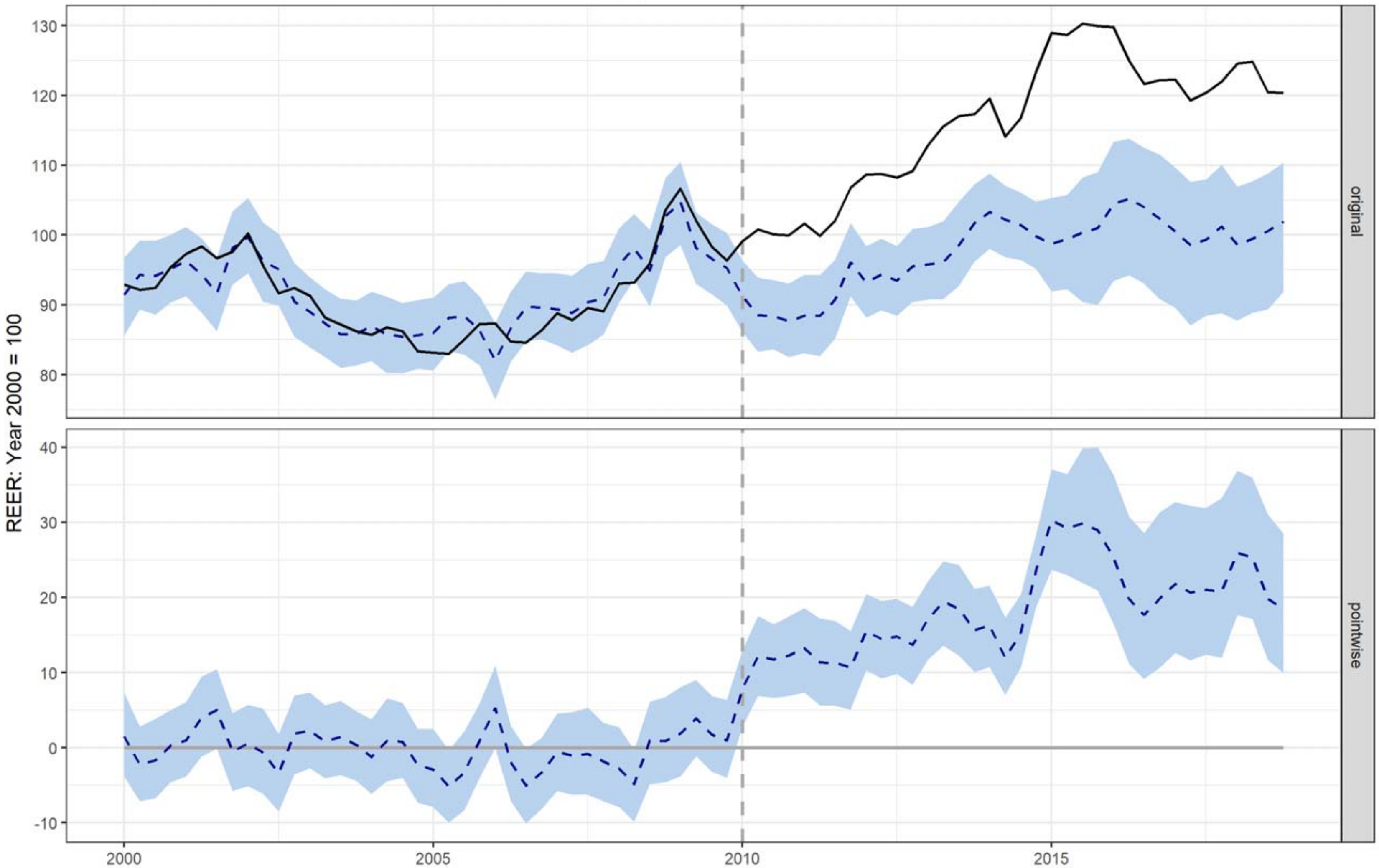


Figure 4.1. Real effective exchange rates and Counterfactuals: Country = CN

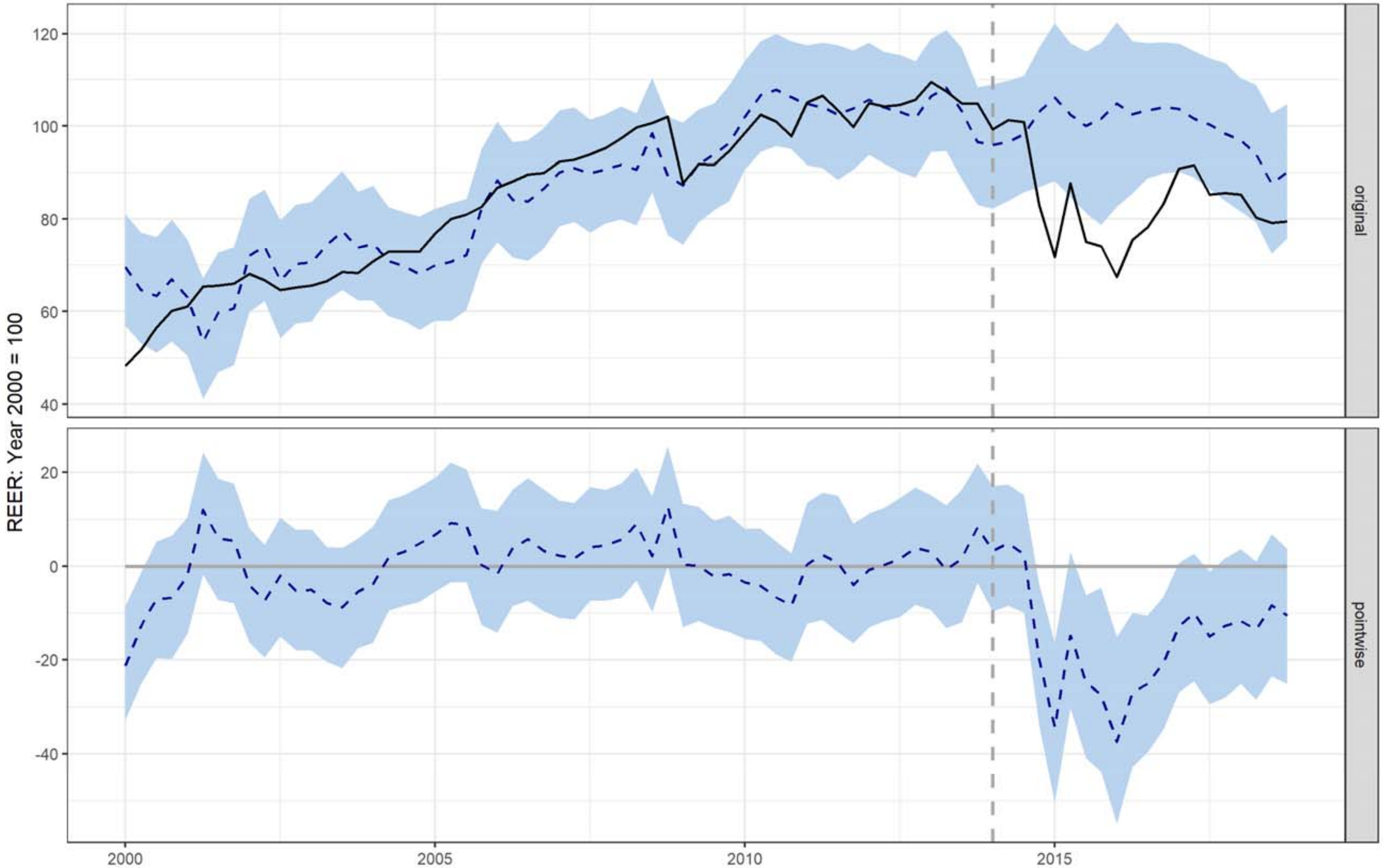
Causal inference using Bayesian structural time-series models; pointwise causal effect.
The first panel shows the data and a counterfactual prediction for the post-treatment period.
The second panel shows the difference between observed data and counterfactual predictions.



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.



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

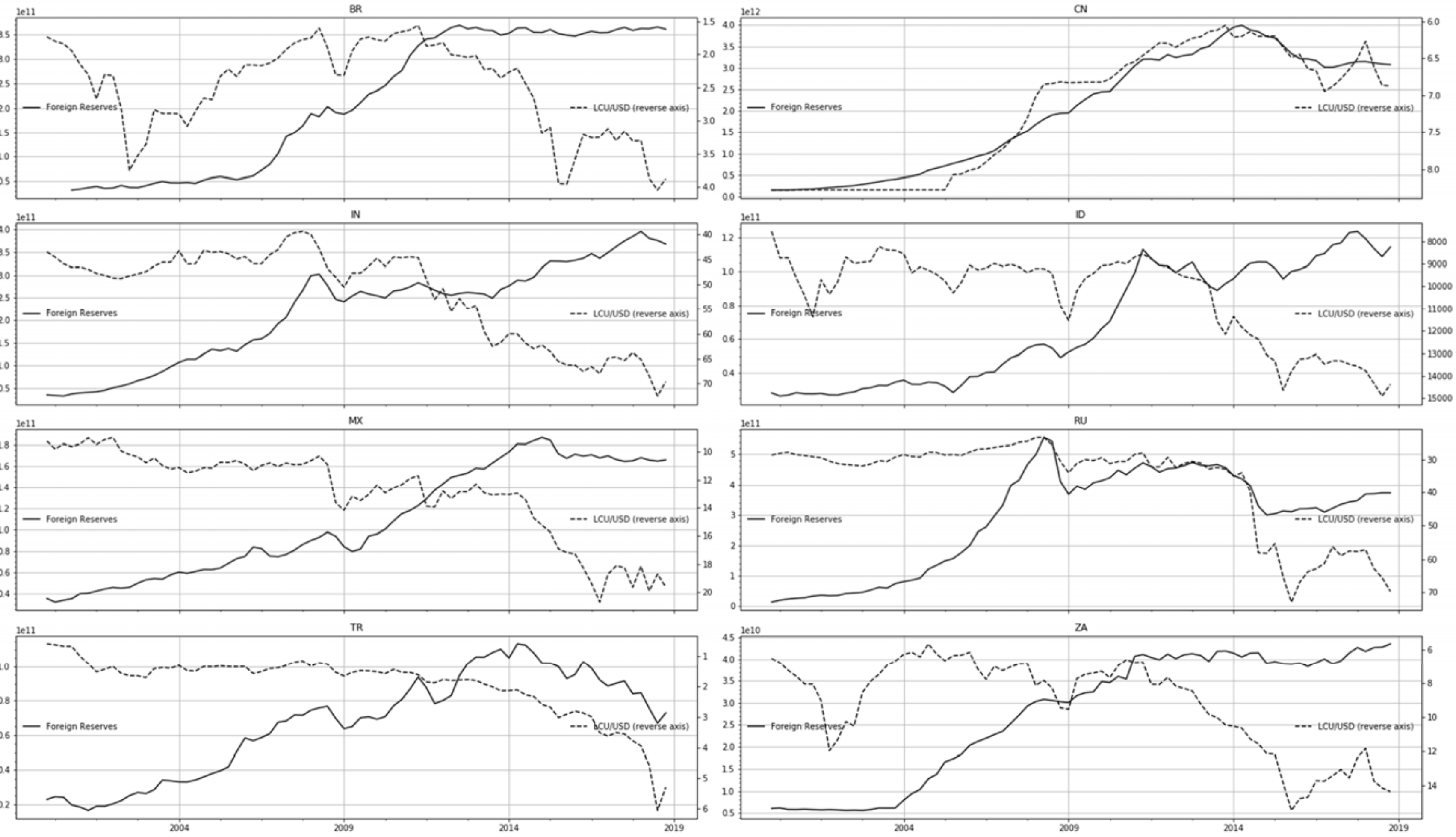
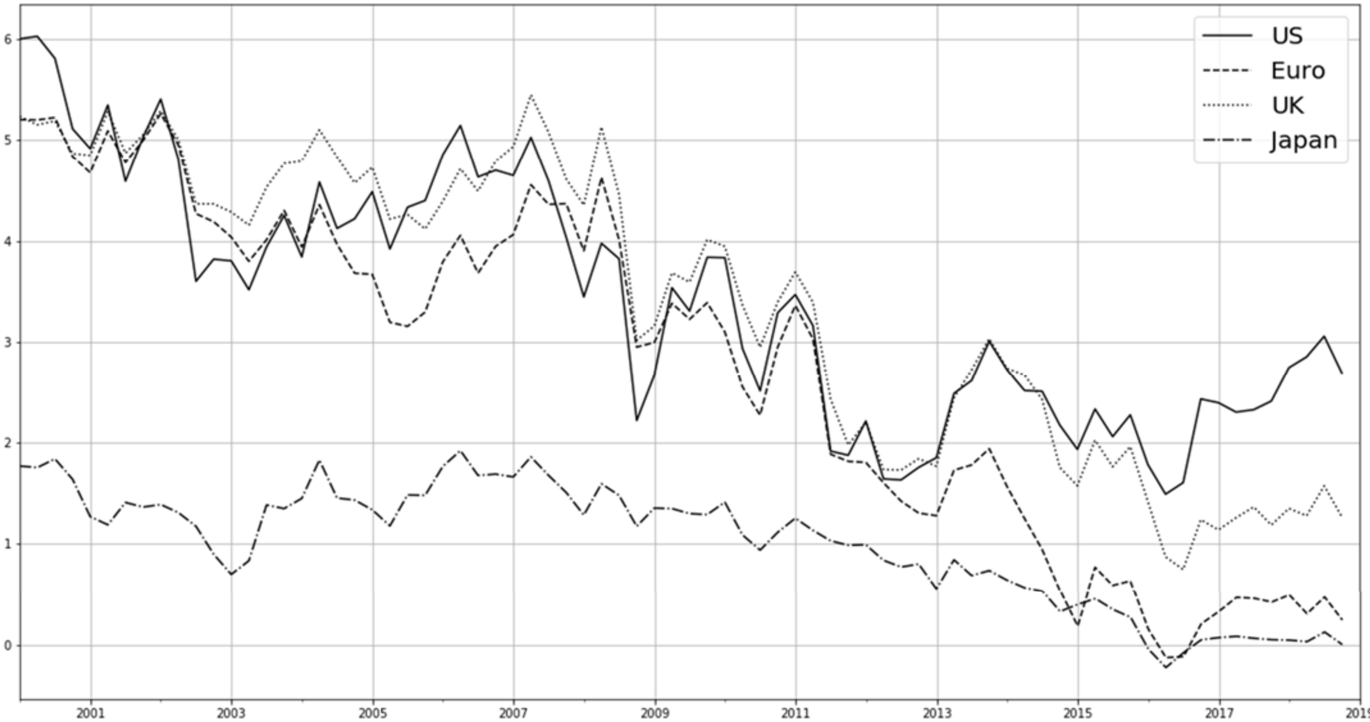


Figure A2. Government Bond Yields: US, Euro, UK, and Japan



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

Figure A3. Sovereign Spreads and REER