# INTERNATIONAL MONETARY FUND

## ASSESSING RESERVE ADEQUACY— FURTHER CONSIDERATIONS —SUPPLEMENTARY INFORMATION

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# RESERVES, CRISIS PROBABILITIES AND LIQUIDITY DRY-UP IN AMS AND EMS[1]

**1.     This chapter investigates the impact of international reserves on (i) the likelihood of currency and banking crisis; and (ii) the frequency of liquidity dry-up episodes in FX markets**. For this work we define currency crises as in Gourinchas and Obstfeld (2011),[2] and banking crises as in Leaven and Valencia (2012). Events of foreign exchange market "liquidity dry-up" are defined as episodes where the daily z-score of bid-ask spreads is larger than 99 percentile of 34 AMs and 49 EMs. The sample of liquidity events encompasses January 1, 1999 to June 30, 2013. Each episode is summed up for each country to annual data so that the number of liquidity dry-up episodes in a year can be interpreted as a proxy for liquidity shortage in FX markets.

**2.     The specification of the estimated models follows Catao and Milesi-Ferretti (2013) but,[3] in contrast to that paper, the regressions are estimated separately for AMs and EMs**. A probit model is used to estimate which factors affect the likelihood of a currency crises (over the period 1975 and 2012). Since the distribution of the number of daily liquidity dry-up episodes is heavily skewed (with a large number of countries not experiencing such episodes), a Tobit model is applied in order to account for the non-linear character of the such liquidity episodes (with the truncation point at 0). More specifically:

- Currency crisis probability model (probit model). The independent variables include (i) net foreign assets/GDP, (ii) net external debt assets/GDP, (iii) net external portfolio equity/GDP, (iv) net FDI position/GDP, (v) FX reserves/GDP, (vi) relative per capita income (against USA, PPP per capita), (vii) current account/GDP (2-year moving average), (viii) REER gap (relative to the 5-year moving average), (ix) VIX, and (x) fiscal gap (relative to 5-year moving average).

- Banking crisis probability model (probit model). A similar model is estimated for the determinants of banking crisis. The only differences are banking crisis dummy is inserted in the left hand side of the regression.

- FX liquidity episodes (Tobit model). The right hand side of the model includes the cost of variation of gross capital inflows/GDP (based on 5-year window) in addition to the variables used for currency crisis probability model, counting increased influence of capital inflows/outflows on liquidity in FX markets in EMs.

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[1] Classification of AMs follows WEO. EMs consists of the 49 countries included in the Fund's internal vulnerability exercise for EMs.

[2] Gourinchas, Pierre-Olivier and Maurice Obstfeld (2011): "Stories of the Twentieth Century for the Twenty First", CEPR Discussion Paper Series, No. 8518.

[3] Catao, Luis and Gian Maria Milesi-Ferretti (2013): "External Liabilities and Crises", IMF WP 13/113.

## A. Results

*Currency crisis probability model*

- Advanced Markets (Table 1a). The estimated model does not explain the probability of a currency crisis well in AMs. Most regressors have neither the correct sign nor are statistically significant. While international reserve has significantly negative sign in some specifications, its effect turns to statistically negligible once current account is added. The poor performance for AMs possibly reflects the relatively small number of currency crisis episodes in AMs.

- Emerging Markets (Table 1b). Estimated coefficients in the regressions for EMs are broadly in line with economic intuition, although net debt assets are not significant and current account and REER gap are at most marginally significant. Empirically, a one standard deviation increase in international reserve/GDP (13 percentage points) would reduce the probability of a currency crisis by about 8 percent.

*Banking crisis probability model*

- Advanced Markets (Table 2a). The results of banking crisis probability model indicate that higher international reserves reduce the banking crisis probability: one standard deviation increase in international reserves in percent of GDP (19 percentage points) reduces the probability of a banking crisis by about 6 percent. This effect could work by providing AM central banks with the ability to provide liquidity support in foreign currency. Interestingly, the other indicators of external vulnerabilities are insignificant in these regressions.

- Emerging markets (Table 2b). The evidence for reserves playing an important role in limiting the risk of banking crisis is less robust than for advanced market economies. Specifically, the impact of reserve buffers on the likelihood of a banking crisis becomes insignificant once global stress, as measured by VIX, in controlled for.

*Liquidity drying-up episodes in FX markets (Table 3)*

- Does nonlinearity matter? Estimated coefficients in the Tobit model have larger coefficients than linear models (fixed effect models) and broadly correct signs. This implies non-linear property of the distribution of the number of liquidity episodes per year across countries and time.

- For EMs, most of the explanatory variables have signs consistent with economic intuition. A one standard deviation increase in international reserves (14 percentage points of GDP) would reduce the number of liquidity dry-up episodes by about 1.4 (around half the average of number of liquidity episodes in EMs of 3, with standard deviation is 9.7). As in the currency crisis probability model, the estimated Tobit regression for AMs does not work well.

## Table 1a. Probit Model on Currency Crisis Probabilities (AMs)

| | AMs | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | coef | t | coef | t | coef | t | coef | t | coef | t | coef | t |
| Net debt assets | -0.068 | -0.458 | -0.071 | -0.471 | 0.150 | 0.687 | 0.007 | 0.037 | 0.038 | 0.145 | 0.068 | 0.260 |
| Net portfolio assets | 0.550 | 1.031 | 0.543 | 1.005 | 0.647 | 1.156 | 0.475 | 0.779 | 0.974 | 0.916 | 1.052 | 0.991 |
| Net FDI position | 0.215 | 0.451 | 0.254 | 0.524 | 0.675 | 1.283 | 0.513 | 0.854 | 1.419 | 1.599 | 1.526* | 1.748 |
| International reserves | -2.050** | -2.053 | -2.067** | -2.071 | -1.600 | -1.602 | -0.680 | -0.625 | -0.487 | -0.337 | -0.365 | -0.263 |
| Relative per capita GDP (PPP) | | | -0.195** | -0.413 | 0.027 | 0.054 | 0.330 | 0.435 | -0.792 | -0.659 | -1.114 | -0.877 |
| Current account balance | | | | | -5.006** | -2.360 | -4.916* | -1.704 | -5.920 | -1.404 | -5.824 | -1.402 |
| REER gap | | | | | | | 1.023 | 0.617 | 0.724 | 0.335 | 0.979 | 0.443 |
| VIX | | | | | | | | | -5.167** | -2.191 | -4.962** | -2.110 |
| Fiscal balance gap | | | | | | | | | | | -2.803 | -0.519 |
| Constant | -1.649*** | -12.943 | -1.502*** | -4.012 | -1.708*** | -4.227 | -2.255*** | -3.621 | -0.681 | -0.636 | -0.478 | -0.433 |
| | -2.764** | -2.220 | -2.919** | -2.052 | -2.868** | -2.098 | -2.646 | -1.483 | -1.824 | -1.104 | -2.036 | -1.111 |
| Number of observations | 1,120 | | 1,120 | | 1,108 | | 887 | | 721 | | 711 | |
| Log likelihood | -168.73 | | -168.65 | | -165.53 | | -90.19 | | -56.77 | | -56.31 | |
| Psedo R-squared | | 0.018 | | 0.019 | | 0.035 | | 0.039 | | 0.086 | | 0.090 |

Sources: WEO, IFS, IIP, Milesi-Ferretti and Lane database, INS, and IMF staff estimates.
Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

## Table 1b. Probit Model on Currency Crisis Probabilities (EMs)

| | EMs | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | coef | t | coef | t | coef | t | coef | t | coef | t | coef | t |
| Net debt assets | -0.230 | -0.996 | -0.265 | -1.149 | -0.216 | -0.885 | 0.237 | 0.583 | 0.007 | 0.013 | -0.142 | -0.253 |
| Net portfolio assets | -1.079 | -0.818 | -1.089 | -0.826 | -1.134 | -0.854 | -2.974* | -1.846 | -2.722 | -1.619 | -2.984* | -1.744 |
| Net FDI position | 1.800*** | 3.508 | 1.819*** | 3.564 | 1.864*** | 3.624 | 1.525** | 2.057 | 2.206** | 2.444 | 2.410*** | 2.586 |
| International reserves | -1.326** | -2.214 | -1.463** | -2.416 | -1.418** | -2.336 | -4.793*** | -3.122 | -4.873*** | -2.907 | -4.901*** | -2.881 |
| Relative per capita GDP (PPP) | | | 0.889** | 1.513 | 0.860** | 1.462 | 0.600*** | 0.670 | 0.241*** | 0.231 | 0.205*** | 0.188 |
| Current account balance | | | | | -0.647 | -0.658 | -3.380 | -1.582 | -3.243 | -1.390 | -3.851 | -1.570 |
| REER gap | | | | | | | 1.003** | 1.981 | 0.974 | 1.429 | 1.253 | 1.602 |
| VIX | | | | | | | | | 5.054*** | 3.021 | 5.247*** | 2.906 |
| Fiscal balance gap | | | | | | | | | | | -9.058** | -2.212 |
| Constant | -1.346*** | -11.876 | -1.506*** | -9.651 | -1.505*** | -9.630 | -1.197*** | -5.080 | -2.193*** | -4.844 | -2.307*** | -4.668 |
| | -15.294 | -0.563 | -15.030 | -0.561 | -14.776 | -0.555 | -15.595 | -0.584 | -15.181 | -0.572 | -14.459 | -0.360 |
| Number of observations | 1,448 | | 1,448 | | 1,445 | | 1,055 | | 912 | | 874 | |
| Log likelihood | -269.14 | | -268.01 | | -267.59 | | -153.98 | | -120.21 | | -110.17 | |
| Psedo R-squared | | 0.039 | | 0.043 | | 0.043 | | 0.079 | | 0.102 | | 0.117 |

Sources: WEO, IFS, IIP, Milesi-Ferretti and Lane database, INS, and IMF staff estimates.
Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

### Table 2a. Probit Model on Banking Crisis Probabilities (AMs)

| | AMs | | | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | coef | t | coef | t | coef | t | coef | t | coef | t | coef | t |
| Net debt assets | -0.171 | -0.908 | -0.196 | -1.116 | -0.019 | -0.072 | 0.029 | 0.098 | 0.104 | 0.325 | 0.121 | 0.351 |
| Net portfolio assets | 0.133 | 0.461 | 0.066 | 0.237 | 0.297 | 0.792 | 0.333 | 0.833 | 0.365 | 0.863 | 0.360 | 0.791 |
| Net FDI position | 0.540 | 1.397 | 0.431 | 1.127 | 0.532 | 1.297 | 0.485 | 1.225 | 1.198* | 1.851 | 1.109* | 1.695 |
| International reserves | -5.202** | -2.502 | -5.117** | -2.442 | -4.579** | -2.188 | -5.365** | -2.263 | -4.311* | -1.886 | -4.759* | -1.959 |
| Relative per capita GDP (PPP) | | | 0.702 | 1.203 | 0.847 | 1.403 | 1.242* | 1.721 | 1.115 | 1.261 | 1.098 | 1.221 |
| Current account balance | | | | | -2.996 | -1.262 | -3.134 | -1.212 | -3.501 | -1.234 | -3.907 | -1.384 |
| REER gap | | | | | | | 0.226 | 0.135 | 2.740 | 1.126 | 2.602 | 1.042 |
| VIX | | | | | | | | | 10.338*** | 4.559 | 9.958*** | 4.351 |
| Fiscal balance gap | | | | | | | | | | | 7.530 | 1.359 |
| Constant | -1.694*** | -11.920 | -2.231*** | -4.735 | -2.362*** | -4.745 | -2.537*** | -4.276 | -4.877*** | -5.047 | -4.765*** | -4.841 |
| Number of observations | 1,120 | | 1,120 | | 1,108 | | 887 | | 721 | | 711 | |
| Log likelihood | -103.76 | | -102.99 | | -102.11 | | -88.39 | | -66.39 | | -65.34 | |
| Psedo R-squared | | 0.037 | | 0.041 | | 0.050 | | 0.061 | | 0.184 | | 0.188 |

Sources: WEO, IFS, IIP, Milesi-Ferretti and Lane database, INS, Laeven and Valencia (2012), and IMF staff estimates.

Note: *** p<0.01, ** p<0.05, * p<0.1

### Table 2b. Probit Model on Banking Crisis Probabilities (EMs)

| | EMs | | | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | coef | t | coef | t | coef | t | coef | t | coef | t | coef | t |
| Net debt assets | -0.282 | -1.084 | -0.349 | -1.342 | -0.360 | -1.309 | -0.604 | -1.474 | -0.777 | -1.340 | -0.771 | -1.261 |
| Net portfolio assets | -2.398* | -1.721 | -2.468* | -1.741 | -2.444* | -1.714 | -2.922* | -1.840 | -2.748 | -1.576 | -3.046* | -1.718 |
| Net FDI position | 1.111** | 2.100 | 1.129** | 2.141 | 1.127** | 2.118 | 0.927 | 1.326 | 2.264** | 2.269 | 2.125** | 2.162 |
| International reserves | -1.382* | -1.664 | -1.648** | -1.961 | -1.649** | -1.962 | -2.345* | -1.860 | -2.082 | -1.514 | -1.933 | -1.378 |
| Relative per capita GDP (PPP) | | | 1.493** | 2.215 | 1.487** | 2.199 | 1.243 | 1.274 | 1.895* | 1.649 | 1.533 | 1.294 |
| Current account balance | | | | | 0.148 | 0.124 | -0.665 | -0.344 | -1.621 | -0.749 | -2.254 | -1.008 |
| REER gap | | | | | | | 2.197*** | 3.231 | 2.658*** | 3.039 | 2.849*** | 2.991 |
| VIX | | | | | | | | | 5.002*** | 2.610 | 5.083** | 2.495 |
| Fiscal balance gap | | | | | | | | | | | -4.225 | -0.964 |
| Constant | -1.682*** | -12.717 | -1.962*** | -10.534 | -1.959*** | -10.498 | -2.061*** | -7.812 | -3.237*** | -6.020 | -3.307*** | -5.727 |
| Number of observations | 1,448 | | 1,448 | | 1,445 | | 1,055 | | 912 | | 874 | |
| Log likelihood | -194.01 | | -191.58 | | -191.48 | | -113.52 | | -89.86 | | -82.26 | |
| Psedo R-squared | | 0.027 | | 0.038 | | 0.038 | | 0.084 | | 0.122 | | 0.127 |

Sources: WEO, IFS, IIP, Milesi-Ferretti and Lane database, INS, Laeven and Valencia (2012), and IMF staff estimates.

Note: *** p<0.01, ** p<0.05, * p<0.1

**Table 3. Models for Drying up Episodes**

| | OLS (Fixed effect) | | | | Tobit | | | |
| | AM | | EM | | AM | | EM | |
| | coef | t | coef | t | coef | t | coef | t |
|---|---|---|---|---|---|---|---|---|
| Net debt assets | -0.101 | -0.383 | -7.599** | -2.324 | 0.132 | 0.317 | -19.683*** | -4.396 |
| Net portfolio assets | 0.478 | 1.234 | 47.437*** | 5.072 | 0.013 | 0.028 | 1.613 | 0.129 |
| Net FDI position | -0.135 | -0.244 | 8.880* | 1.867 | -1.317 | -1.399 | -1.897 | -0.318 |
| International reserves | -4.694*** | -2.593 | 1.049 | 0.168 | -0.512 | -0.389 | -30.257*** | -3.436 |
| Relative per capita GDP (PPP) | 0.862 | 0.260 | -24.001 | -1.419 | -5.385*** | -2.652 | -2.322 | -0.254 |
| Current account balance | 20.388*** | 4.326 | 17.471 | 1.527 | 22.202*** | 3.612 | 50.847*** | 2.813 |
| REER gap | -1.175 | -0.530 | 3.069 | 0.744 | 1.872 | 0.434 | 7.561 | 0.937 |
| VIX | 9.653*** | 5.060 | 23.743*** | 3.553 | 30.487*** | 7.195 | 80.895*** | 5.240 |
| Fiscal balance gap | -0.564 | -0.126 | -18.738 | -1.102 | -10.936 | -1.288 | -92.127** | -2.518 |
| Cost of variation of capital inflows | -0.006 | -1.011 | 0.179 | 1.589 | -0.005 | -0.507 | 0.406* | 1.801 |
| Constant | -1.029 | -0.447 | 4.498 | 1.343 | -4.012** | -2.306 | -24.630*** | -5.688 |
| Sigma in Tobit model (Heckman) | | | | | 3.758*** | 16.791 | 16.544*** | 19.269 |
| Number of observations | 363 | | 535 | | 363 | | 535 | |
| R-squared | 0.145 | | 0.150 | | | | | |
| Adjusted/Pseudo R-squared | 0.047 | | 0.056 | | 0.066 | | 0.030 | |
| Chi squared | | | | | | 77.312 | | 65.426 |
| Log-Likelihood | | | | | -543.10 | | -1,043.18 | |

Sources: WEO, IFS, IIP, Milesi-Ferretti and Lane database, INS, Bloomberg, and IMF staff estimates.
note: *** p<0.01, ** p<0.05, * p<0.1

# IMPLICATIONS FOR INTERVENTION FROM MODELS OF CURRENCY CRISIS

3.      **The literature on currency crises provides differing views on the appropriate role and timing of intervention**. The literature on currency crises has traditionally been grouped into three generations, each identifying a separate reason for the crisis, and thus differing roles for intervention.[4]

- *First generation*—inconsistent policies. Policy inconsistency is the driver of the crisis in first generation currency crisis models. Specifically, there is an inconsistency between the exchange rate policy (peg) of the country and the (lose) fiscal or monetary policy (credit grows faster than money demand) pursued by the government. In such circumstances, the peg is ultimately doomed and no level of reserves can prevent the crisis, reflecting the fact that doing so would have the authorities defend a peg at an unsustainable parity.

- *Second generation*—temptation of inconsistent policies. The second generation models do not assume policy inconsistency prior to crisis. However, the fact that the government might be tempted to trigger an "escape clause," and devalue to pursue expansionary policy, can create the possibility of self-fulfilling speculative attacks on the currency—the timing of an any speculative attack depends on whether or not policy might change and vice versa. However, the probability of an attack does depend on the underlying economic fundamentals of the policy,

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[4] Sarno and Taylor (2001) and Sarno and Taylor (2002, Chapter 8) provide nice summaries of this literature.

with a stronger preference for low inflation or a smaller potential targeted expansion (output in line with potential) reducing the prospects of a crisis. The probability of a crisis is increasing with the (political) cost the authorities face for abandoning the peg—the higher this cost the larger the likely profits of speculators—suggesting that prolonged and intense intervention may, in some circumstances, increase the probability of a speculative attack. Having said that, intervention may play a role guiding speculators' ex ante exchange rate expectations, and hence limit the risk of a crisis.

- **Third generation**—financial fragility. In the third generation model of currency crises, the realization of implicit contingent liabilities from large financial intermediaries drives the crisis. The ultimate crisis follows large private outflows which come as a result of the financial crisis. While reserves may not have an apparent role here, reserves potentially provide scope to provide foreign currency liquidity to solvent financial institutions.

# EXAMINING DETERMINANTS OF FX SELLING INTERVENTION AND ITS IMPACT ON FX DEPRECIATION/PACE OF DEPRECIATION IN EMS

4.      **This chapter investigates determinants of FX selling intervention and its impact on FX depreciation in EMs, mainly following specifications in Adler and Tovar (2011)**[5]. The bottom line is that FX selling intervention can affect pace of depreciation while quantitatively negligible impact on depreciation.

5.      **Past literature on the impact of FX intervention to exchange rate provides a mixed picture, but leaning toward a positive assessment of the effectiveness of FX intervention**. An extensive survey by Sarno and Taylor (2001)[6] concluded—mainly based on studies on advanced countries—(i) official intervention can be effective especially if the intervention is publicly announced and concerted and provided that it is consistent with the underlying stance of monetary and fiscal policy, and (ii) studies during the 1990s are largely supportive of the effectiveness of intervention compared to those in the 1980s, reflecting improved data on intervention and FX rate expectations. Reviewing literature on FX intervention during the 2000s (Ostry et al. 2012)[7] concluded the effectiveness of sterilized intervention in EMs is mixed, but generally more favorable than in the advanced economy context. A recent study using panel data of FX intervention for 15 countries,

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[5] Adler, Gustavo and Camilo E. Tovar (2011): "Foreign Exchange Intervention: A Shield against Appreciation Winds?" IMF WP 11/165.

[6] Sarno Lucio and Mark P. Taylor (2001): "Official Intervention in the Foreign Exchange Market: Is it Effective and, if so, How Does it Work?" *Journal of Economic Literature*, Vol. 39, No. 3, page 839-868.

[7] Ostry, Jonathan, Atish Ghosh, and Marcos Chamon (2012): "Two Targets, Two Instruments: Monetary Exchange Rate Policies in Emerging Market Economies", IMF SDN/12/01.

Adler and Tovar (2011) found that FX purchasing interventions slow the pace of appreciation and it is more effective in the context of already overvalued exchange rates.

**6.      The exercise outlined in this chapter consists of the following three stages**.

- *Calculation of FX intervention*. It is calculated for 49 EMs, spanning since January 2004 using monthly reserve data taken from IFS, with the impact of the two 2009 SDR allocations removed, and with estimated valuation and income effects removed assuming COFER portfolio shares and using market exchange rates and bond yields8. In the estimates, negative (positive) number indicates sale (purchase) of FX. We also undertake the same empirical exercise using actual intervention data reported by six EM central banks.

- *First stage regression to estimate a central bank's FX intervention policy reaction function*. Specifications follow that in Adler and Tover (2011). The regression is estimated country-by-country, allowing heterogeneity of the response function across countries. In order to highlight asymmetry of the response function, the regression is estimated separately when central bank purchases and sells FX. The dependant variable is estimated FX intervention (in percent of GDP). The right hand side includes the lagged change in exchange rate (defined as a first difference of natural logarithm—a large number indicates a depreciating exchange rate), REER misalignment (based on either CGER or EBA), 3-month speed of exchange rate change, intra-month exchange rate volatility, and international reserve (in percent of GDP).

- *Second stage regression on the exchange rate equation*. Given the implied FX intervention derived from each country-by-country regression, the exchange rate equation—following Adler and Tovar (2011)—is estimated using a simple fixed effects model, where it is estimated separately for the case where foreign exchange is purchased , and where it is sold in the first stage. Three types of relationships are estimated: where the  dependant variable is (i) the level of the bilateral exchange rate against the US$ (natural logarithm); (ii) the appreciation/depreciation of bilateral exchange rate defined as its first log-difference; and (iii) the pace of appreciation/depreciation defined as the second difference. The right hand side includes interest rate differentials (short-term interest rates), EMBI spreads, commodity prices (metal, energy and food prices) to control high frequency of terms of trade shocks, VIX, and the extent of foreign exchange intervention.

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[8] Counting large fluctuations of the implied intervention relative to official intervention (available countries), filtered (3-month) number of the implied intervention is used for regressions.

## A.  Results of the first stage regression—asymmetry and trade off of policy objective

**7.      The summary statistics of the estimated coefficients for international reserves with FX selling intervention have negative sign and larger negative value for countries with less flexible FX regime**. This may imply that (i) building up reserves would be important for countries with less flexible FX regime in order to keep intervention effective, as is (ii) the use of the limited reserves stock the country has: central bank with less flexible exchange rate regimes would intervene more to pressures in foreign markets when they have sufficient international reserves.

| Coefficients of International Reserves to Determine FX Selling Intervention (Median of 49 EMs, based on 1st stage regressions) | |
|---|---|
| Total | -0.013 |
| Free floating & floating | -0.006 |
| Other managed arrangement | -0.012 |
| Non-floating & other managed | -0.027 |

**8.      Another implication derived from the first stage regression is a trade-off of policy objectives for central bank when central bank sales FX**. Intuitively a larger positive coefficient for exchange rate misalignment suggests that central bank cares more about addressing the misalignment while a larger positive coefficient for international reserve indicates that central bank cares more about maintaining of building international reserves. In general central banks cannot freely choose both of the level of FX misalignment and international reserves under flexible exchange rate regime (based on AREAER) without capital controls. Therefore, central bank would face a negative trade-off over the choice of the level of FX misalignment and international reserve. The estimated coefficients are consistent with this intuition: flexible FX regime countries face a negative trade-off as a group.



Policy Trade-Off in Non-peg FX Regime EMs: FX Selling Intervention (Based on individual country regressions)

$y = -0.4846x - 0.0143$
$R^2 = 0.1753$
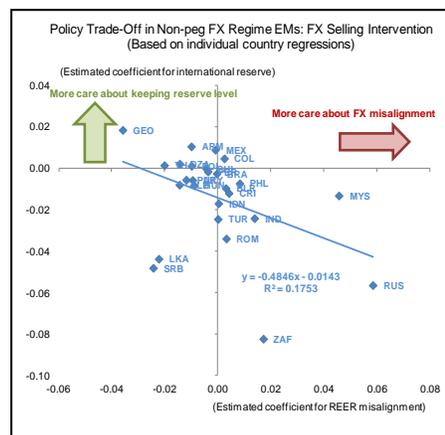
## B.  Output of the second stage regression—negligible impact on depreciation but effective for the pace of depreciation

**The results are presented in Table 4.**

*Depreciation*. The size of intervention has negative (statistically marginally significant) coefficient, but this is counterintuitive because it means that depreciation coincides with massive FX selling by central banks. Perhaps, this observation may reflect measurement



Estimated Coefficients of FX Selling Intervention to Depreciation

1/ Same methodology but based on 5 countries.
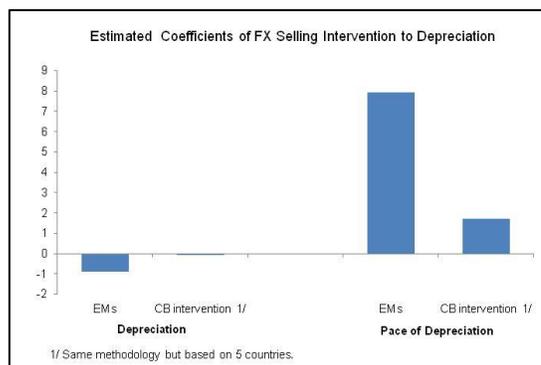
errors of the estimated FX intervention sample based on 49 countries. It may also be influenced, to some extent, by a very large shock (e.g., the Lehman shock) to the capital account which could not be absorbed by intervention in the sample period. In order to check the former effect, the same regression is estimated only using our five countries sample based on actual intervention data.[9] With the official intervention data, the impact on depreciation declines to the level which is quantitatively negligible. While the results of the additional regression should be interpreted with caution, the estimated regressions imply that FX selling intervention does not quantitatively affect exchange rate depreciation. These findings are qualitatively similar to the results on the impact of FX intervention to *appreciation* in Adler and Tovar (2011).

***Pace of depreciation***. The estimated coefficient is positive and statistically significant, suggesting that FX selling intervention does affect the pace of depreciation. This observation is consistent with the finding, in Adler and Tovar (2011), that purchasing intervention can slow the pace of appreciate.

**Table 4. Panel Regression on the Determinants of FX Depreciation when Central Bank Conduct FX Selling Intervention**

| | FX selling intervention, based on implied intervention | | | | FX selling intervention, based on actual intervention data (5 countries) | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Depreciation 1/ | | Pace of depreciation | | Depreciation 1/ | | Pace of depreciation | |
| | coef | t | coef | t | coef | t | coef | t |
| Implied intervention, selling | -0.886* | -1.864 | 7.936*** | 2.516 | -0.060* | -1.833 | 1.708*** | 5.367 |
| Interest rate differentials | 0.006*** | 3.894 | 0.006 | 0.564 | 0.002 | 0.332 | 0.007 | 0.127 |
| Sovereign spreads | 0.001 | 0.721 | 0.007 | 1.097 | 0.035*** | 8.539 | -0.023 | -0.582 |
| Metal prices | -0.049*** | -2.859 | 0.031 | 0.276 | -0.049* | -1.939 | -0.314 | -1.268 |
| Energy prices | -0.044*** | -3.613 | -0.016 | -0.198 | 0.001 | 0.061 | 0.041 | 0.234 |
| Food prices | -0.101*** | -4.284 | 0.075 | 0.479 | -0.096*** | -2.886 | -0.346 | -1.065 |
| VIX | 0.021*** | 4.082 | 0.028 | 0.808 | 0.022*** | 2.625 | 0.134* | 1.660 |
| Constant | 0.004** | 2.067 | 0.037*** | 2.836 | -0.000 | -0.255 | 0.003 | 0.199 |
| # of observations | 1,300 | | 1,300 | | 465 | | 465 | |
| R-square | 0.155 | | 0.007 | | 0.344 | | 0.077 | |

note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

1/ Negative sign indicates appreciation.

# LIQUIDITY SWAP LINES DURING THE GLOBAL FINANCIAL CRISIS

**9.** **During the global financial crisis, temporary US dollar liquidity swap lines (USD swap lines) have been put in place promptly**. In light of the mounting pressures in US dollar funding markets across the globe, especially in Europe, Federal Reserve Bank (FED) provided the first set of USD swap lines to the European Central Bank (ECB) and Swiss National Bank (SNB) in 2007 (Table 5)

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[9]Chile, Colombia, Mexico, Peru and Turkey.

 The swap lines were designed to provide "foreign central banks with the capacity to deliver U.S. dollar funding to institutions in their jurisdictions during times of market stress," and "prevent the spread of strains to other markets and financial centers."[10]

| Table 5. USD Liquidity Swap Lines | | | | | |
|---|---|---|---|---|---|
| Date | | Country/Area | Size (USD bil) | Duration | Lending rate |
| 2007 | Dec 12 | **Euro, Switzerland** | 55, 12 | O/N-3M | Fixed (OIS+100bp) or Variable |
| 2008 | Sep 18 | **Japan, UK, Canada** *(size expanded)* **ECB, Switzerland** | 60, 40, 10 110, 27 | | |
| | Sep 24 | Australia, Sweden, Norway, Denmark | 10, 10, 5, 5 | | |
| | Sep 29 | *(size expanded)* **Euro, Switzerland, Japan, UK, Canada** Australia, Sweden, Norway, Denmark | 240, 60, 120, 80, 30, 30, 30, 15, 15 | | |
| | Oct 13-14 | *(size expanded)* **Euro, Japan, UK, Switzerland** | No fixed limit | | Fixed (OIS+100bp) |
| | Oct 28 | New Zealand | 15 | | |
| | Oct 29 | Brazil, Mexico, Korea, Singapore | 30 each | | |
| 2010 | Feb 1 | Termination | - | - | - |
| | May 9 | **Euro, Japan, UK Switzerland, Canada** | No fixed limit (CAN: 30) | 1W-3M | Fixed (OIS+100bp) |
| 2011 | Nov 30 | **Euro, Japan, UK Switzerland, Canada** | ↓ | ↓ | 1W-3M, Fixed (OIS+50bp) |
| 2013 | Oct 31 | **Euro, Japan, UK Switzerland, Canada** | ↓- | ↓ | Bilateral liquidity swap arrangements were converted to standing arrangements.[1] |
| 1/ For details see http://www.federalreserve.gov/newsevents/press/monetary/20131031a.htm | | | | | |

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[10] M. Fleming et al, "The Federal Reserve's Foreign Exchange Swap Lines," Federal Reserve Bank of New York, April 2010.

**10.     The coverage and terms of US dollar (USD) swap lines have been flexible to cope with sudden and further deterioration in the funding market**.  Immediately after Lehman Shock (September 15), the US Federal Reserve promptly expanded USD swap lines to provide broader access of US dollars in view of the sudden freeze in the global US dollar funding market, including the FX swap market.  The swap lines were expanded first to include Bank of Japan (BOJ), Bank of England (BOE), and Bank of Canada (BOC) and then eventually to include Nordic, Pacific Asian, and Latin American central banks.  During this time, the size of swap lines more than doubled in a matter of less than 2 weeks for most AMs before the Federal Reserve announced a removal of the caps on lines for ECB, SNB, BOJ, and BOE.  The lending rate under USD fund supplying operations to financial institutions was amended to fixed rate only to eliminate any uncertainty on auctioned rates with expiration date was extended three times.  These measures allowed the financial institutions to borrow any amount at a transparent fixed rate for longer period of time so long as they held appropriate collateral in each jurisdiction regardless of currency denomination.

**11.     USD swap lines have been quickly reactivated when deemed necessary.**  After being terminated for only 3 months, the Federal Reserve quickly reactivated USD swap lines in May 2010 for the ECB, SNB, BOJ, BOE, and the BOC in response to a reemergence of US dollar funding strains.  At first, the terms (i.e. size, duration, and lending rate) were inherited from the previous USD swap lines.  However, in light of heightening counterparty risks, particularly with European banks, in late 2011 and a stigma attached to bidding for USD fund supplying operations, the premium on lending rate was reduced by 50bps in November 2011 to improve financial institutions' usage of the operations.  This resulted in a substantial increase in bid, for USD liquidity swap lines. Several USD swap lines were also extended.

**12.     As precautionary instrument, non-USD swap lines have also been put in place swiftly** (Table 6).  Non-USD swap lines, which were first arranged bilaterally between the FED and other central banks in 2009, were reactivated and strengthened in 2011 to establish a mesh of swap lines among the Federal Reserve, the ECB, SNB, BOJ, BOE, and the BOC, the same members in the currently active USD swap lines.

### Table 6. Non-USD Liquidity Swap Lines among Mature Market Countries

| Date | | Country/Area | Size | Duration | Lending rate |
|---|---|---|---|---|---|
| 2009 | Apr 6 | *Between US and* **Euro/Japan /UK/Switzerland** | €80bil, ¥10tri, £30bil, CHF40bil | | TBD by Fed |
| 2010 | Feb 1 | Termination | - | | - |
| 2011 | Nov 30 | *Among* **US, Euro, Japan, UK, Canada, Switzerland** | No fixed limit | Max. 3M | TBD by CBs |
| 2013 | Oct 31 | **US, Euro, Japan, UK, Canada, Switzerland** | | | Bilateral liquidity swap arrangements were converted to standing arrangements.[1] |
| 1/ For details see http://www.federalreserve.gov/newsevents/press/monetary/20131031a.htm | | | | | |

# MEASURING MARKET DYSFUNCTION IN THE SWAP MARKET

**13.      Dysfunction in FX swap markets occurs when liquidity suddenly tightens and transactions freeze**. In such circumstances the covered interest parity (CIP) condition tends to not hold. This condition states that, under normal market conditions, arbitrage ensures that the cost of e.g. off-shore US dollar funding through FX swaps is close to the on-shore unsecured US dollar funding rate:

$$\frac{F_{t,t+s}}{S_t}\left(1 + r^f\right) = 1 + r^d \qquad ,$$

where $S_t$ and $F_{t,t+s}$ represent the spot and forward exchange rates, and $r^f$ and $r^d$ represent the uncollateralized foreign and domestic interest rates. Large deviations from CIP signal stress in the FX swap market.[11] Here, FX market dysfunction episodes are defined as extreme multi-day deviations from CIP where implied US dollar FX swap spreads exceed their 99th percentile value (for the 3 month tenor). Normal market conditions are assumed to be restored when this differential returns to below the threshold level for 5 consecutive trading days. The currencies in the sample include the Australian dollar, British pound sterling, Canadian dollar, Swiss franc, Danish kroner, euro, Hong Kong dollar, Icelandic krona, Japanese yen, Norwegian krone, New Zealand dollar, Swedish krona, and Singapore dollar. The Czech koruna, Israeli shekel, and Korean won are not included in the sample as these were considered EM currencies until recently. From January 1989 to August 2013, 85 episodes of market dysfunction can be identified across the 13 currency pairs included in the sample.

# CAN INTERNATIONAL RESERVE LEVEL AFFECT CONSUMPTION GROWTH VOLATILITY?

**14.      This chapter briefly presents an empirical study on the relation between private consumption growth volatility and international** reserves in the framework of consumption smoothing, paying attention to compare explanatory power across different reserve adequacy metrics. In a simplified dynamic optimization problem of private consumption with a floor of international reserve, consumption behavior follows a standard Euler equation unless the constraint on international reserve binds currently or is likely to (in the sense of the constraint having an expected value) in the future. The solution suggests:

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[11] See Baba, N. and F. Packer (2009), From turmoil to crisis: dislocations in the FX swap market before and after the failure of Lehman Brothers, BIS Working Paper No. 285, and Barkbu B. and L. Ong (2010), FX Swaps: Implications for Financial and Economic Stability, IMF working paper 10/55.

- *A negative correlation between volatility of consumption growth and international reserve level.* This reflects that (i) consumption growth volatility should be minimized without binding constraints and (ii) low international levels of reserves indicate a bigger possibility of facing a binding constraint in the future; as well as
- *A non-linear relationship between international reserves and consumption growth volatility.* This is due to a "smooth pasting" feature of the optimal solution of a stochastic dynamic optimization problem and a declining marginal benefit of international reserve level in order to avoid binding the constraint.

**15.      Unfortunately, it is very difficult to analytically solve the optimal solution because an interesting case with binding the constraint on reserves has a corner solution**. Therefore, we use a reduced form model to examine the above two features (see Box 1). The dependent variable is consumption growth volatility. The right hand side of the model includes terms of trade (ToT) as a proxy for external demand shocks, FX regime (from AREAER) as a proxy for the economic flexibility to absorb external shocks, international reserves (represented by alternate reserve adequacy metrics where natural logarithm of these metrics are used to reflect the non-linearity), and the current account balance as a proxy of existing (domestic/external) imbalances[12].

**16.      The cross-country data set includes 44 EMs. Macroeconomic data is taken from WEO.** Data for the reserve adequacy metrics is from the WEO and IFS. The FX regime is from the Fund's Annual Report on Exchange Arrangements and Exchange Restrictions. In order to avoid endogeneity, consumption volatility is based on that during 2008-12 while all dependent variables are either values in 2007 or, for the current account balance, averaged over 2002-07.

**17.      The estimated parameters (Table 7) suggest most of the variables have the appropriate sign, but the natural logarithm of the reserve adequacy metrics are not generally statistically significant**. However, a term combining the natural logarithm of ARA EM Metric with current account balance is statistically significant, suggesting that widened deficit with low international reserves would result in bigger consumption growth volatility. Other traditional Metrics do not have statistically significant coefficients, either individual or when interacted with the current account balance, suggesting less explanatory power of the role of international reserves to smooth consumption growth (Table 8).

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[12] This is because 5-year average during the previous 5 years is used in regression. By taking average of 5 years, business cycle effects would be almost filtered out and thus the variable could be treated as structural external/domestic imbalances/external vulnerabilities. Also, volatility of inflation and structural fiscal balance (averaged over 5 years) were examined as alternatives too. However, their performance was not nice.

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### Box 1. Derivation of Euler Equation and Regression

All variables are per capita base. Representative agent's problem is

$$\text{Max } E \sum \beta^t u(c_t)$$

Subject to $a_{t+1} = a_t + fa_t$ , $y_t = c_t + x_t - m_t$ , $R_{t+1} = R_t + fa_t + ca_t$,
$ca_t = x_t - m_t + ra_t$, $fa_t = \rho fa_{t-1} + \varepsilon_t^{fa}$, $y_t = \theta y_{t-1} + \varepsilon_t^y$, $R_t \geq R$, where $R$ indicates international reserves. As in the literature, rational expectation is assumed.

First order conditions of the dynamic optimization problem are:

$$u'(c_t) = \lambda_t \qquad\qquad (1)$$

$$-\lambda_t + \beta E \lambda_{t+1} + \beta E \psi_{t+1} = 0 \qquad\qquad (2)$$

$$R_{t+1} = R_t + fa_t + y_t - c_t \qquad\qquad (3)$$

$$R_t \geq R \qquad\qquad (4)$$

where $\lambda$ and $\psi$ are Lagrange multipliers of constraints (3) and (4) respectively. Note that the latter is zero when constraint (4) does not bind.

How can we derive regression?

Combining equations (1) and (2) gives

$$u'(c_t) = \beta E u'(c_{t+1}) + \beta E \psi_{t+1}$$

Taking linear approximation around the steady state (or Taylor series expansion) gives

$$u''(c^*)(c_t - c^*) = \beta E[u''(c^*)(c_{t+1} - c^*)] + \beta E[(\psi_{t+1} - \psi^*] \text{ or}$$

$$c_t - c^* = \beta E[(c_{t+1} - c^*)] + \frac{\beta}{u''(c^*)} E[(\psi_{t+1} - \psi^*]$$

Rearranging the above would give,

$$\frac{c_{t+1} - c_t}{c^*} = (1 - \beta) E \frac{c_{t+1} - c^*}{c^*} + \frac{u'(c^*)}{-u''(c^*)c^*} \frac{\beta}{\lambda^*} E(\psi_{t+1} - \psi^*)$$

Using the approximation of natural logarithm,

$$\frac{c_t - c^*}{c^*} \cong \ln(1 + \frac{c_t - c^*}{c^*}) = \ln(1 + \frac{c_t}{c^*} - 1) = \ln c_t - \ln c^*$$

Therefore, the final form of regression is

$$\ln c_{t+1} - \ln c_t = (1 - \beta) E(\ln c_{t+1} - \ln c^*) + \frac{\beta}{\gamma_R^* \lambda^*} E(\psi_{t+1} - \psi^*) \quad (5)$$

where $\gamma_R^*$ is the relative risk aversion at the steady state.

## Table 7. Estimated Regressions on Determinants of Consumption Growth Volatility, 1993-2012

| RAMs | ARA EM Metric | | | | | | | | | | | | | | Imports (3M) | | ST debt (100%) | | M2 (30%) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | coef | t | coef | t | coef | t | coef | t | coef | t | coef | t | coef | t | coef | t | coef | t | coef | t |
| ToT volatility | 0.111 | 0.62 | 0.127 | 0.78 | 0.125 | 0.72 | 0.143 | 0.43 | 0.083 | 0.28 | -1.279 | -1.37 | -0.548 | -0.83 | 0.028 | 0.09 | -0.055 | -0.19 | -0.240 | -0.98 |
| Trade partner growth volatility | 0.945* | 1.86 | 0.632* | 1.73 | 1.008* | 1.81 | 1.297** | 2.29 | 1.188** | 2.12 | 5.113*** | 2.88 | 3.384* | 1.77 | 1.395** | 2.39 | 1.285* | 1.72 | 2.794*** | 5.41 |
| Cross term of ToT volatility and FX regime | | | | | | | -0.000** | -0.01 | 0.009** | 0.26 | 0.018 | 0.42 | 0.000** | 0.01 | 0.007** | 0.18 | 0.032 | 0.91 | 0.039* | 1.13 |
| Cross term of trade partner growth volatility and FX regime | | | | | | | -0.175** | -1.58 | -0.144** | -1.84 | -0.139 | -1.48 | -0.108** | -1.17 | -0.190** | -2.98 | -0.192 | -2.49 | -0.220* | -3.89 |
| Cross term of ToT volatility and RAM | | | | | | | | | | | 0.282 | 1.34 | 0.149** | 0.92 | | | | | | |
| Cross term of trade partner growth volatility and RAM | | | | | | | | | | | -0.867 | -1.76 | -0.545** | -1.14 | | | | | | |
| FX regime (AREAER) | -0.205 | -0.99 | -0.218 | -1.01 | -0.247 | -1.12 | 0.159 | 0.40 | | | | | | | | | | | | |
| RAM | -0.357 | -0.46 | 0.044 | 0.05 | | | | | | | | | | | | | | | | |
| Current account balance over GDP | -0.167 | -1.52 | -2.719*** | -2.69 | -0.242** | -2.17 | -2.556** | -2.29 | -2.543** | -2.33 | -0.121 | -1.21 | -2.190** | -2.25 | -2.752** | -2.46 | -0.764 | -0.94 | -1.677* | -1.91 |
| Cross term of current account balance and RAM | | | 0.528** | 2.53 | | | 0.503** | 2.19 | 0.497** | 2.22 | | | 0.428** | 2.16 | 0.501** | 2.35 | 0.124 | 0.75 | 0.332* | 1.79 |
| NFA over GDP | | | | | 0.017 | 0.72 | | | | | | | | | | | | | | |
| Banking crisis dummy | 1.396 | 1.34 | 0.634 | 0.57 | 1.307 | 1.28 | 0.879 | 0.77 | 0.842 | 0.76 | 1.398 | 1.26 | 0.821 | 0.72 | 1.467 | 1.43 | 1.442 | 1.42 | 1.216 | 1.25 |
| Transition countries (until 2002) | 7.189 | 1.22 | 6.181 | 1.50 | 7.150 | 1.24 | 6.532 | 1.58 | 6.519 | 1.60 | 7.671 | 1.45 | 6.580 | 1.55 | 5.278 | 1.57 | 7.519 | 1.39 | 8.964* | 1.66 |
| 1998-2002 dummy | -0.227 | -0.34 | -0.544 | -0.65 | -0.389 | -0.53 | -0.357 | -0.50 | -0.406 | -0.57 | -0.113 | -0.13 | -0.248 | -0.30 | 0.092 | 0.11 | -0.226 | -0.36 | -0.472 | -0.81 |
| 2003-07 dummy | -1.393 | -1.19 | -1.789 | -1.38 | -1.273 | -1.11 | -1.671 | -1.37 | -1.670 | -1.37 | -1.599 | -1.23 | -1.669 | -1.33 | -1.373 | -1.08 | -1.611 | -1.30 | -1.527 | -1.45 |
| 2008-12 dummy | -0.712 | -0.41 | -1.077 | -0.67 | -0.773 | -0.46 | -0.435 | -0.27 | -0.511 | -0.32 | -0.340 | -0.18 | -0.410 | -0.24 | 0.238 | 0.13 | 0.049 | 0.03 | -2.239 | -1.54 |
| _cons | 4.643 | 1.28 | 3.168 | 0.76 | 3.626** | 1.99 | 1.420 | 0.57 | 2.261* | 1.75 | 2.743* | 1.94 | 2.455* | 1.91 | 2.057 | 1.45 | 2.608* | 1.82 | 2.462** | 2.15 |
| Number of observations | 107 | | 107 | | 107 | | 107 | | 107 | | 107 | | 107 | | 107 | | 107 | | 101 | |
| F | | 8.436 | | 7.559 | | 8.536 | | 5.603 | | 5.933 | | 8.496 | | 7.006 | | 7.917 | | 6.873 | | 10.791 |
| R2 | 0.450 | | 0.559 | | 0.452 | | 0.576 | | 0.575 | | 0.530 | | 0.587 | | 0.590 | | 0.495 | | 0.575 | |
| Adjusted R2 | 0.393 | | 0.508 | | 0.395 | | 0.522 | | 0.525 | | 0.470 | | 0.529 | | 0.542 | | 0.436 | | 0.523 | |
| *Memorandum items* | | | | | | | | | | | | | | | | | | | | |
| Points of marginal impcat of shocks/imbalances offset by FX regime and RAM | | | | | | | | | | | | | | | | | | | | |
| FX regime (ToT) | | | | | | | 362.16 | 0.01 | -8.80 | -0.14 | | | | | -3.81 | -0.06 | 1.74 | 0.22 | 6.15* | 1.87 |
| FX regime (Trade partner) | | | | | | | 7.40** | 2.16 | 8.23** | 2.59 | | | | | 7.34*** | 2.86 | 6.69** | 2.67 | 12.72*** | 4.54 |
| RAM (current account balance) | | | 172.41*** | 4.53 | | | 160.97*** | 4.62 | 166.60*** | 4.80 | | | | | 241.72*** | 4.63 | 469.80 | 0.52 | 157.15** | 2.35 |

note: *** p<0.01, ** p<0.05, * p<0.1

**Table 8. Results of Exclusion Test**
**(P-value of the test. Null hypothesis: Exclusion does not have impact)**

| Remaining | Excluding | Entire sample period (1) | Drop 2008-12 (2) | Only 2008-12 1/ (3) |
|---|---|---|---|---|
| ARA EM Metric | Imports (3 month) | 0.191 | 0.121 | 0.468 |
| Imports (3 month) | ARA EM Metric | 0.424 | 0.956 | 0.065 |
| ARA EM Metric | ST debt (100%) | 0.336 | 0.697 | 0.316 |
| ST debt (100%) | ARA EM Metric | 0.012 | 0.038 | 0.063 |
| ARA EM Metric | M2 (30 %) | 0.046 | 0.001 | 0.074 |
| M2 (30 %) | ARA EM Metric | 0.048 | 0.137 | 0.718 |

1/ Based on cross country regressions

# RESERVES COVERAGE AND THE LIKELIHOOD OF EXCHANGE MARKET PRESSURE EVENTS

**18.      The proposed metric seems predict periods of exchange market pressure (EMP) and other crisis events better than traditional metrics.** To compare the relative performance of various metrics in accounting for vulnerability to EMP events, a series of logit regressions relating the probability of such an event with each of the metrics were estimated (Table 9). Given that the general policy environment is likely at least as important as reserves in explaining these events, the regressions also accounted for additional explanatory variables, including cyclically adjusted primary balance, and primary balance gap. The proposed metric outperforms all the traditional metrics, with higher reserves coverage against this metric significantly reducing the probability of EMP event. As a robustness test, a logit regression was also run against a sample of extreme crisis-related events studied in Laeven and Valencia (2012), as well as the 2009 Crisis Program Review.[13]  In both samples low reserves coverage against the metric also significantly explains the crisis events.

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[13] International Monetary Fund, 2009, "Review of Recent Crisis Programs" (International Monetary Fund: Washington, DC)

## Table 9. Comparison of Various Reserve Adequacy Metrics: Logit Regressions, 1990-2012

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | EMP Crisis Events | | | | | | |
| Reserves/Metric 1 (RAM1) | -0.306* | -0.309* | -0.412* | | | | | | | | | |
| | (0.173) | (0.162) | (0.216) | | | | | | | | | |
| Reserves/Metric 2 (RAM2) | | | | -0.327* | -0.329** | -0.433** | -0.372** | -0.329** | -0.412** | -0.395* | -0.290 | -0.386* |
| | | | | (0.174) | (0.154) | (0.204) | (0.175) | (0.153) | (0.173) | (0.210) | (0.184) | (0.200) |
| Cyc. Adj. Primary Balance/GDP | | 0.0654* | | | 0.0777** | | 0.0789** | 0.0784** | 0.0901** | 0.0756** | 0.0781* | 0.0602 |
| | | (0.0356) | | | (0.0388) | | (0.0390) | (0.0390) | (0.0409) | (0.0382) | (0.0403) | (0.0537) |
| Primary Balance Gap | | | 0.0268 | | | 0.0267 | | | | | | 0.00714 |
| | | | (0.0177) | | | (0.0178) | | | | | | (0.0139) |
| Reserves/STD(RM) | | | | | | | 0.000243 | | | | | |
| | | | | | | | (0.000441) | | | | | |
| Reserves/GEFN (STD RM + CAB) | | | | | | | | -0.0000129 | | | | |
| | | | | | | | | (0.0000240) | | | | |
| Reserves/Broad Money | | | | | | | | | -0.000000632 | | | |
| | | | | | | | | | (0.00000219) | | | |
| Reserves in months of imports | | | | | | | | | | 0.0224 | | |
| | | | | | | | | | | (0.0453) | | |
| Reserves/Total portfolio Liabilities | | | | | | | | | | | -0.0000961 | |
| | | | | | | | | | | | (0.000121) | |
| Constant | -1.805*** | -1.848*** | -1.737*** | -1.760*** | -1.790*** | -1.686*** | -1.788*** | -1.788*** | -1.664*** | -1.838*** | -1.789*** | -1.724*** |
| | (0.228) | (0.227) | (0.289) | (0.233) | (0.224) | (0.283) | (0.221) | (0.224) | (0.241) | (0.245) | (0.244) | (0.283) |
| Number of observations | 612 | 532 | 440 | 595 | 518 | 433 | 517 | 518 | 507 | 518 | 518 | 412 |

Source: Staff estimates
Notes: All independent variables are calculated using the previous year's data. Standard errors are reported in paretheses under coefficient estimates; with ***, **, and *, respectively de  ** p<0.05  *** p<0.01"

**Table 9. Comparison of Various Reserve Adequacy Metrics: Logit Regressions, 1990-2012 (Cont.)**

| | (13) | (14) | (15) | (16) | (17) | (18) | (19) | (20) | (21) | (22) | (23) | (24) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | CPR Crisis Events | | | | | |
| Reserves/Metric 1 (RAM1) | -1.312*** | -1.423** | -2.539*** | | | | | | | | | |
| | (0.508) | (0.654) | (0.691) | | | | | | | | | |
| Reserves/Metric 2 (RAM2) | | | | -1.318*** | -1.461** | -2.212*** | -1.383** | -1.457** | -1.476** | -2.465** | -1.336** | -3.120*** |
| | | | | (0.484) | (0.651) | (0.615) | (0.656) | (0.654) | (0.629) | (1.160) | (0.558) | (0.247) |
| Cyc. Adj. Primary Balance/GDP | | 0.0189 | | | 0.0180 | | 0.0184 | 0.0195 | 0.0210 | 0.00835 | 0.00881 | 0.0190 |
| | | (0.0798) | | | (0.0836) | | (0.0854) | (0.0846) | (0.0958) | (0.0699) | (0.0867) | (0.0332) |
| Primary Balance Gap | | | -0.0212** | | | -0.0220*** | | | | | | -0.0219*** |
| | | | (0.00781) | | | (0.00781) | | | | | | (0.00820) |
| Reserves/STD(RM) | | | | | | | -0.00123*** | | | | | |
| | | | | | | | (0.000375) | | | | | |
| Reserves/GEFN (STD RM + CAB) | | | | | | | | -0.0000891 | | | | |
| | | | | | | | | (0.0000764) | | | | |
| Reserves/Broad Money | | | | | | | | | 0.00000251 | | | |
| | | | | | | | | | (0.00000190) | | | |
| Reserves in months of imports | | | | | | | | | | 0.232* | | |
| | | | | | | | | | | (0.122) | | |
| Reserves/Total portfolio Liabilities | | | | | | | | | | | -0.00144 | |
| | | | | | | | | | | | (0.00218) | |
| Constant | -3.560*** | -3.514*** | -3.219*** | -3.494*** | -3.424*** | -3.373*** | -3.349*** | -3.423*** | -3.408*** | -3.831*** | -3.228*** | -3.483*** |
| | (0.603) | (0.727) | (0.843) | (0.597) | (0.734) | (0.834) | (0.739) | (0.735) | (0.716) | (0.658) | (0.809) | (1.035) |
| Number of observations | 608 | 528 | 440 | 592 | 515 | 433 | 514 | 515 | 504 | 515 | 515 | 412 |

Source: Staff estimates

Notes: All independent variables are calculated using the previous year's data. Standard errors are reported in paretheses under coefficient estimates; with ***, **, and *, respectively denoting significance at 1, 5, and 10 percent levels.

### Table 9. Comparison of Various Reserve Adequacy Metrics: Logit Regressions, 1990-2012 (Concl.)

| | (25) | (26) | (27) | (28) | (29) | (30) | (31) | (32) | (33) | (34) | (35) | (36) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Banking Crisis Events | | | | | | |
| Reserves/Metric 1 (RAM1) | -2.191*** | -2.854*** | -2.817*** | | | | | | | | | |
| | (0.588) | (0.837) | (0.998) | | | | | | | | | |
| Reserves/Metric 2 (RAM2) | | | | -2.088*** | -2.651*** | -2.700*** | -2.584*** | -2.651*** | -2.784*** | -3.998*** | -2.523*** | -3.744** |
| | | | | (0.552) | (0.784) | (0.887) | (0.776) | (0.784) | (0.775) | (1.157) | (0.680) | (1.491) |
| Cyc. Adj. Primary Balance/GDP | | -0.161* | | | -0.156* | | -0.158* | -0.156* | -0.129 | -0.0902 | -0.155* | -0.416*** |
| | | (0.0915) | | | (0.0921) | | (0.0914) | (0.0920) | (0.0930) | (0.0913) | (0.0895) | (0.155) |
| Primary Balance Gap | | | -0.0250* | | | -0.0266* | | | | | | -0.0270* |
| | | | (0.0145) | | | (0.0146) | | | | | | (0.0140) |
| Reserves/STD(RM) | | | | | | | -0.000757 | | | | | |
| | | | | | | | (0.000531) | | | | | |
| Reserves/GEFN (STD RM + CAB) | | | | | | | | -0.0000316 | | | | |
| | | | | | | | | (0.000115) | | | | |
| Reserves/Broad Money | | | | | | | | | 0.000000336 | | | |
| | | | | | | | | | (0.00000180) | | | |
| Reserves in months of imports | | | | | | | | | | 0.359** | | |
| | | | | | | | | | | (0.153) | | |
| Reserves/Total portfolio Liabilities | | | | | | | | | | -0.000638 | | |
| | | | | | | | | | | (0.00118) | | |
| Constant | -1.944*** | -1.343** | -1.858** | -1.979*** | -1.453** | -1.912*** | -1.406** | -1.452** | -1.297** | -2.517*** | -1.437** | -1.480 |
| | (0.519) | (0.652) | (0.752) | (0.506) | (0.634) | (0.716) | (0.633) | (0.634) | (0.632) | (0.850) | (0.640) | (0.923) |
| Number of observations | 333 | 295 | 232 | 323 | 287 | 228 | 287 | 287 | 278 | 287 | 287 | 218 |

Source: Staff estimates

Notes: All independent variables are calculated using the previous year's data. Standard errors are reported in paretheses under coefficient estimates; with ***, **, and *, respectively denoting significance at 1, 5, and 10 percent levels.

# THE STERILIZATION COST OF RESERVES

**19.      Central banks in EMs increasingly sterilize the accumulation of their large reserves holdings by issuing domestic public debt**. This chapter estimates the quasi-fiscal sterilization cost of reserves, which is measured by the spread between the yields on reserves and the interest paid to issue domestic government bonds or bills. By estimating the determinants of domestic bond yield spreads, this chapter shows that beyond some threshold of domestic government debt to GDP, higher domestic public debt possibly partly (reflecting larger sterilization activities) increase a government's financing costs at an increasing rate.

## A.  Sample

**20.      We use annual data for 1990-2013. The 21 EMs and AMs** with available data for the dependent and explanatory variables include Argentina, Belgium, Brazil, Chile, China, Colombia, Croatia, Greece, Hungary, India, Indonesia, Malaysia, Norway, Philippines, Poland, Russia, Slovak Rep., South Africa,Thailand, Turkey, and Ukraine. Data is taken from Spring 2013 WEO database and from public sources (Bloomberg and IFS).

## B.  Methodology

**21.      To estimate quasi-fiscal costs associated with sterilization, we run a panel (country and year) fixed effects OLS regression of the fundamental determinants of long-term government bond yield spreads**. While country fixed effects capture time-invariant country heterogeneity, year fixed effects are meant to account for global shocks or common factors that can affect interest rates simultaneously across countries (in potentially different ways). This is particularly important in regressions of government bond yields in integrated capital markets, given that failure to capture these global factors would results in error terms being cross-sectionally dependent. When we proxy for global factors by the VIX index, we do not include year effects. The benefit from doing so is to actually quantify the effect of changes in global risk aversion during the sample period.

**22.      In the baseline specification, the dependent variable is the difference between yields on long-term yields and long-term US bond yields**. By way of robustness, we also run regressions with the spread between long-term domestic yields and short-term US (T-bill) yields. Among the right side determinants for our baseline regression, the fiscal variables include domestic public debt to GDP and its square term, our main variables of interest, and the cyclically adjusted primary fiscal balance to GDP.[14] We control for



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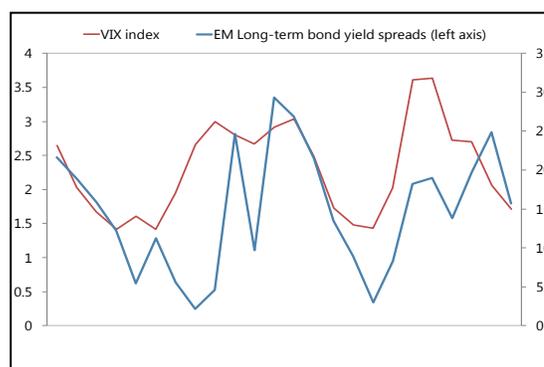
[14] Using WEO data, we compute domestic public debt as the different between total government debt and government external debt.

monetary policy by including short-term interest rates and inflation, and also control for the potential real growth rate. Finally, we also include the change in country's financial development (which we measure by the change in the ratio of credit to private sector to GDP.

**23.     The main premise is that the relationship between debt and yields is a non-linear one: beyond a certain threshold of domestic public debt, further increases in debt are associated with higher yields**. We therefore include debt and its square term to capture these non-linearities. Baseline regression results show this non-linear pattern and allow us to compute the threshold beyond which yields are increasing at an increasing rate with domestic debt.

**24.     Our results (Table 10) are also robust to using lags of the dependant fiscal variables to attenuate endogeneity concerns as well as to re-estimate the relationship using 2SLS with lags of fiscal variables as instruments**. On endogeneity, if automatic fiscal stabilizers worsen the primary fiscal balance (and raise debt) during a downturn in the business cycle, while at the same time monetary easing leads to a fall in long-term interest rates, fiscal balance and interest rates may be positively correlated, while debt and interest rates negatively correlated (Laubach, 2009). These forces work against what we would expect to have: positive/negative relationship between debt/primary fiscal balance and bond yields. Additional robustness checks show that our results are robust to running the regression in differences to account for non-stationarity of some the variables (Table 11).[15]

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[15] Using the Im, Pesaran and Shin (2007) unit root test, we find that our dependent variables are stationary. Among controls, primary balance, inflation and potential growth are stationary, while domestic debt to GDP and its square term are non-stationary.

**Table 10. Spreads and Public Debt**

| Dependent variable: Long-term bond yield spreads | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Domestic Public Debt/GDP | -0.234*** | -0.231*** | -0.259*** | -0.235*** |
| Domestic Public Debt/GDP$^2$ | 0.00367** | 0.00351** | 0.00377** | 0.0040*** |
| Primary balance to GDP | 0.105 | 0.106 | 0.016 | -0.012 |
| Potential GDP growth | -0.479* | -0.595* | -0.622** | -0.601* |
| Inflation | 0.050 | 0.032 | 0.044 | 0.004 |
| Short-term interest rate | 0.472*** | 0.408*** | 0.404*** | 0.334** |
|  |  |  |  |  |
| Reserves to metric |  | -0.009* |  | -0.010* |
| Change in financial openness |  |  | -0.055* | -0.055 |
| VIX index |  | 0.042 | 0.015 | 0.138*** |
|  |  |  |  |  |
| Country fixed effects | YES | YES | YES | YES |
| Year fixed effects | YES | NO | NO | NO |
| Observations | 256 | 178 | 229 | 167 |
| Countries | 21 | 18 | 21 | 17 |
| R-squared | 0.47 | 0.62 | 0.44 | 0.65 |
|  |  |  |  |  |
| *Implied Domestic Debt to GDP threshold* | *31.2%* | *32.9%* | *34.4%* | *29.4%* |
| *Sample EMs above threshold* | *6* | *4* | *3* | *8* |

Note: ***,**,* indicate statistical significance at 1, 5, and 10 percent respectively, with robust standard errors. The dependent variable in columns 1, 2 and 3 is the difference between domestic long-term (LT) bond yield and US LT bond yield. The dependent variable in column 4 is the difference between domestic LT bond yield and US T-bill rate.

**Table 11. Spreads and Public Debt–Robustness**

| Dependent variable: Long-term bond yield spreads | OLS with 1-year lags of fiscal variables | OLS in differences | 2SLS with lags of fiscal variables as instruments |
|---|---|---|---|
|  | 1 | 2 | 3 |
| Domestic Public Debt/GDP | -0.098* | -0.133*** | -0.192*** |
| Domestic Public Debt/GDP$^2$ | 0.00123** | 0.00308** | 0.00235*** |
| Primary balance to GDP | 0.015 | 0.140 | -0.312** |
| Potential GDP growth | -0.481* | -0.394 | -0.399*** |
| Inflation | 0.035 | -0.011 | 0.152* |
| Short-term interest rate | 0.447*** | 0.313** | 0.253** |
|  |  |  |  |
| Country fixed effects | YES | YES | YES |
| Year fixed effects | YES | YES | YES |
| Observations | 253 | 235 | 247 |
| Countries | 21 | 21 | 21 |
| R-squared | 0.33 | 0.32 | 0.24 |
|  |  |  |  |
| *Implied Domestic Debt to GDP threshold* | *40.1%* | *21.6%* | *40.9%* |
| *Sample EMs above threshold* | *2* | *10* | *2* |

Note: ***,**,* indicate statistical significance at 1, 5, and 10 percent respectively, with robust standard errors.

# SURVEY RESPONSES

**25.** **The paper was also informed by a survey of the membership**. There were a total of 40 responses, of which almost half were from advanced economies. The survey gathered member country views on the motive and use of reserves, analytical frameworks to assess precautionary reserve adequacy and approach to intervention

Legend:   AM ■   EM ▲   Total ■

1. For what purposes does your institution hold reserves?

2. What liquidity needs do reserves cover?

3. Which institutions are involved in determining the appropriate level of reserves?

4. Which of the following metrics, if any, do you use to assess reserve adequacy?
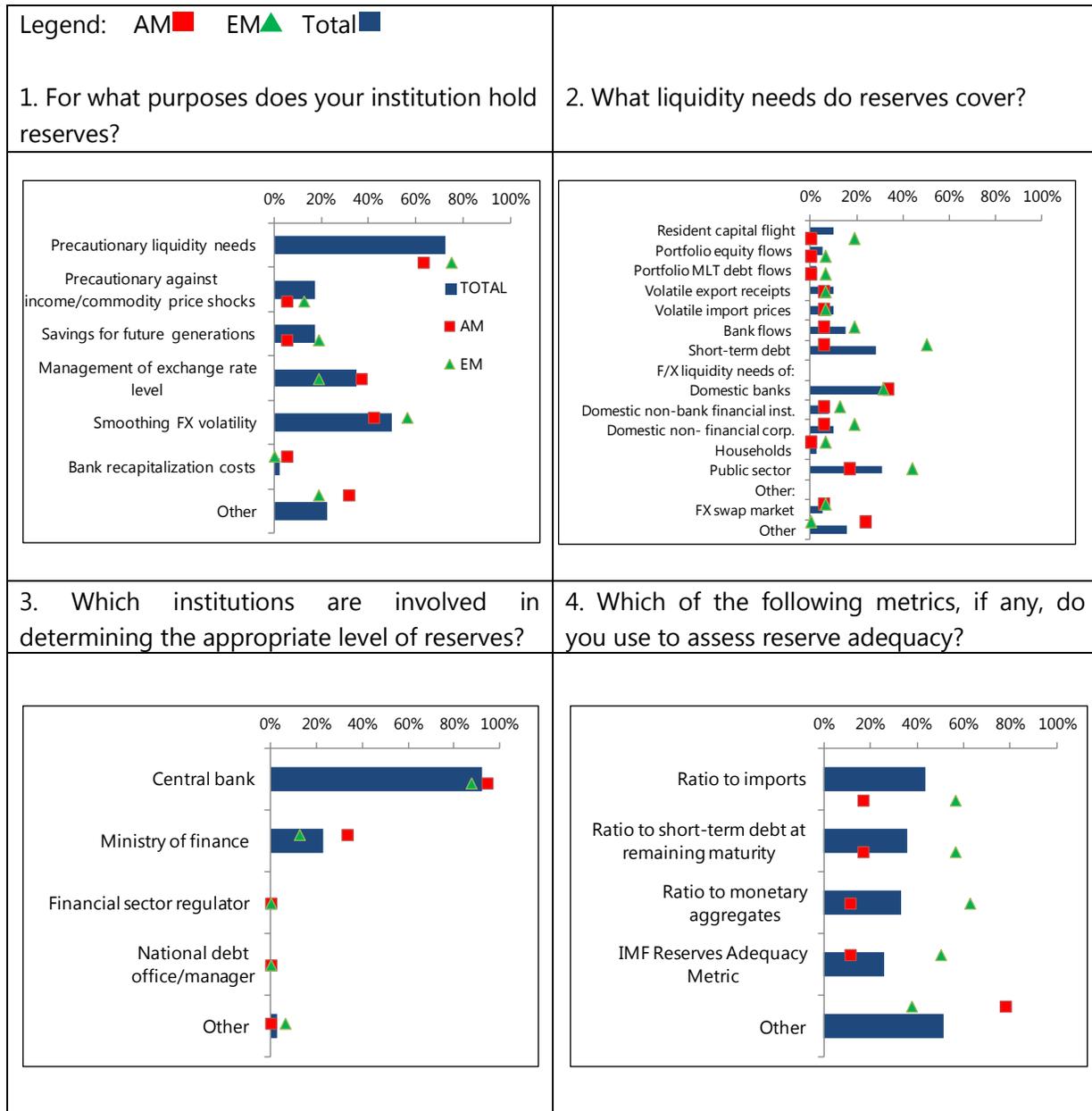
**5. Do you use any other analytical framework to assess reserves adequacy?**
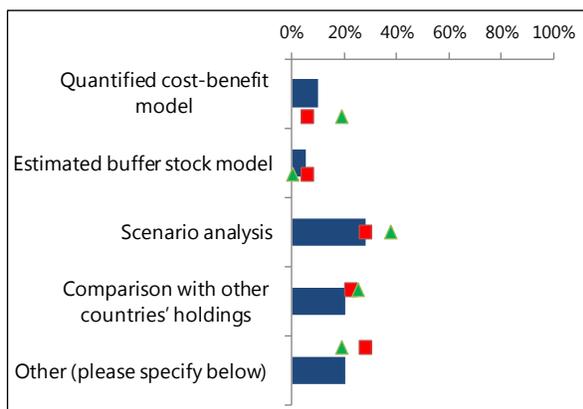


**6. Do you regard the current level of reserves as adequate for precautionary purposes?**
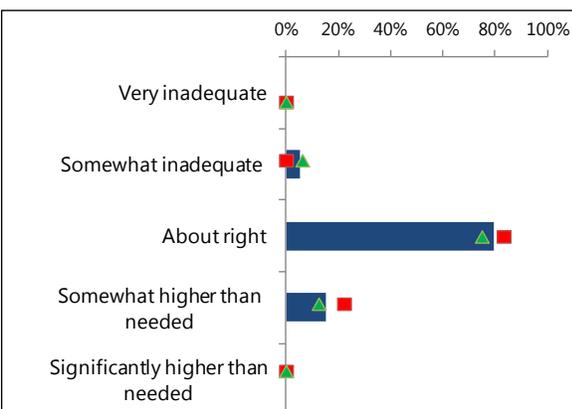


**7. Has your assessment of your country's reserve needs for insurance reasons increased since the 2008 crisis?**
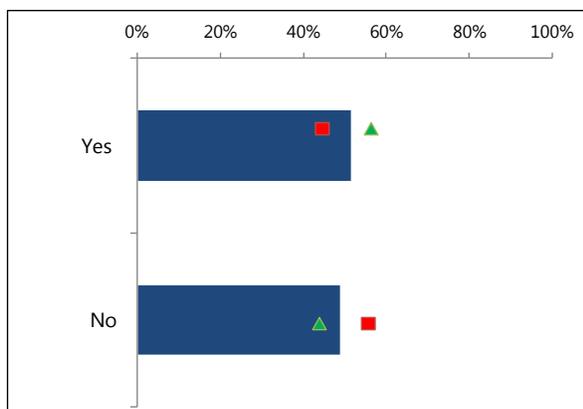


**8. How do you assess the cost of holding reserves?**
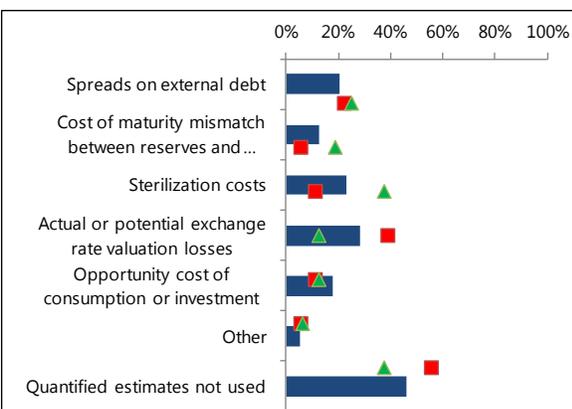


**9. What derivatives do you use as part of your intervention strategy?**
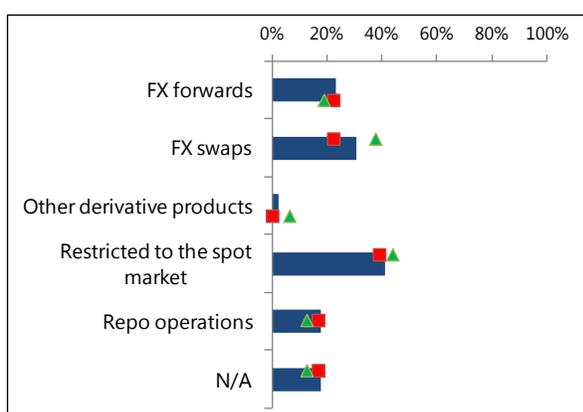


**10. What other instruments would you consider as playing a similar role to reserves?**
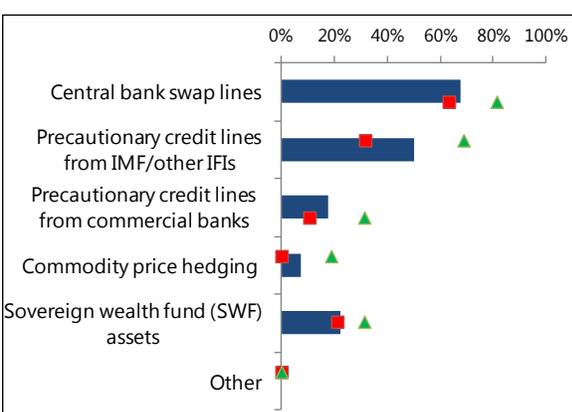
| 11. What policy instruments do you use to limit the potential need to provide FX liquidity support to banks (e.g. minimize potential liquidity needs)? | 12. Do you: |
|---|---|
|  |  |
| 13. To what extent is reserve usage to stem exchange rate of outflow pressures governed by rules? | 14. What indicators do you monitor to assess foreign exchange market conditions? |
|  |  |
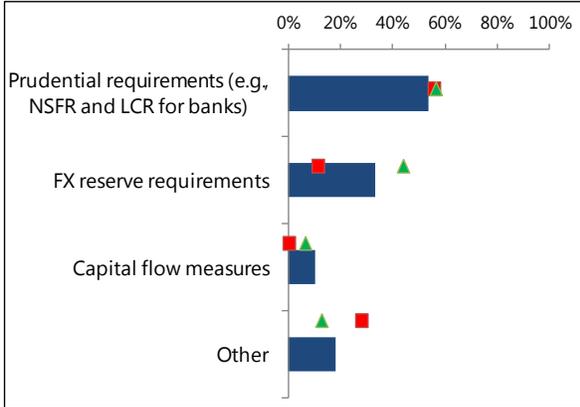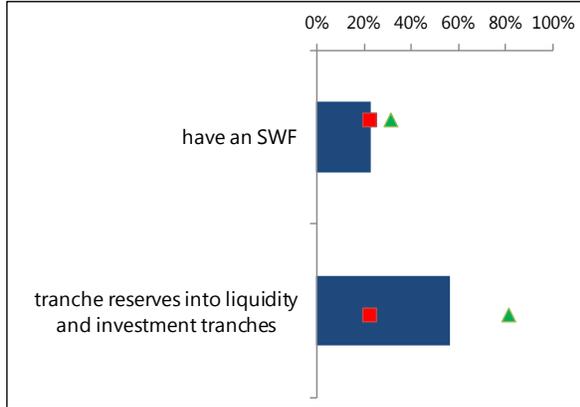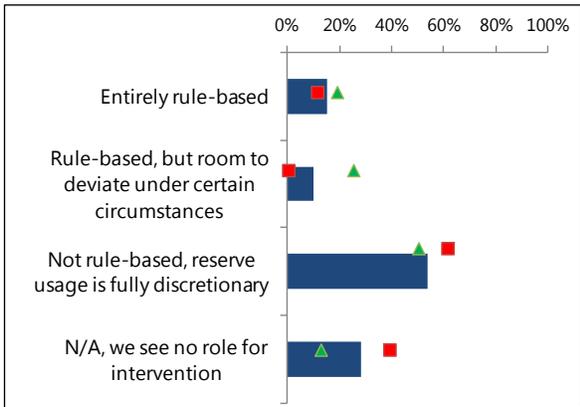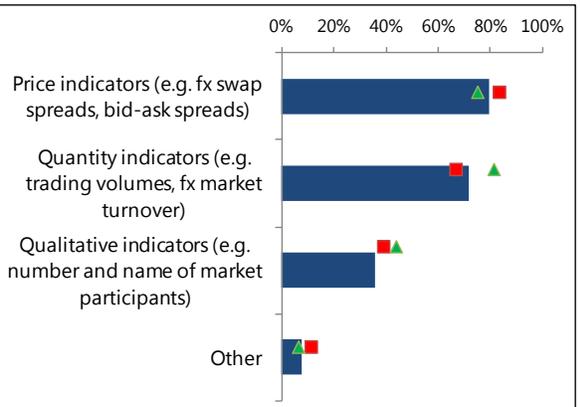
# SURVEY OF LOW-INCOME COUNTRY TEAMS ON USAGE OF THE 2011 LIC RESERVE ADEQUACY METRIC

**26.      This section provides a summary of a recent survey of country teams' experiences in using the 2011 LIC metric**. The survey was conducted to gauge needs for enhancing the operational usefulness of the LIC metric.

**27.      About half of the LIC country teams have used the metric in their recent discussions with country authorities on reserve adequacy** (Figure 1).[16] There is significant regional heterogeneity in usage. Three-quarters of African Department (AFR) country teams have used the metric compared to about two-fifths and one-third of Western Hemisphere Department (WHD) and Middle East and Central Asia (MCD) LIC teams, respectively.[17] The LIC metric tends to be used as a complement to other existing approaches; the most common approach for policy discussion with the authorities remains the 3-month import coverage (Figure 2).  About 8 LICs have supplemented their reserve adequacy analysis with the EM metric (Figure 1).[18]

### Figure 1. Usage of Reserves Metrics by IMF Country Teams

*(percent of respondents, total respondents: 58)*



| | YES (Used LIC metric) 48% | NO (Did not use LIC metric) 52% |
|---|---|---|
| **Other Metric Used:** | | |
| 3 months of imports | 20% | 41% |
| Broad money coverage | 8% | 14% |
| Short-term debt coverage | 8% | 9% |
| Other Metric* | 8% | 7% |
| IMF 2011 EM metric** | 7% | 5% |
| | 0% | 1% |
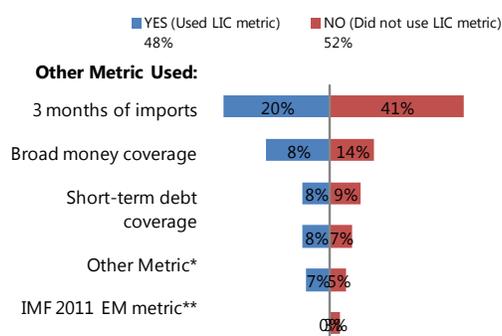
### Figure 2. Which Metric was used most often in the Recent Discussions with the Authorities on Reserves?

*(percent of respondents, total respondents: 58)*



- IMF 2011 LIC optimal reserve metric — 33%
- 3 months of imports — 46%
- Broad money coverage — 3%
- Other — 9%
- None — 5%
- Did not answer — 5%

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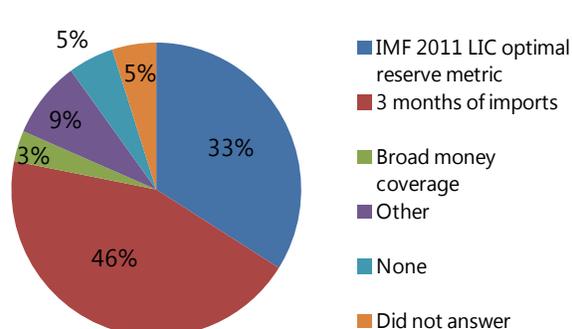
[16] Survey response was high. There were 55 responses out of 60 non-currency union countries and one response each for the CEMAC, WAEMU, and ECCU currency unions since reserve adequacy is typically assessed at the union level.

[17] There is only one LIC country team in EUR and it did not use the metric.

[18] Armenia and Georgia graduated from PRGT eligibility in March 2013 (although they remain eligible until the expiration of their current programs).

**28.    The adequate level of reserves derived using the LIC metric tends to be higher than that from other approaches to reserve adequacy assessment**. This is particularly the case in AFR LICs where the median adequate level of reserves using the LIC metric is about 6 months, albeit with large margins, while that from other traditional metrics is about 4 months. In addition, AFR country teams that used the LIC metric tended to have median actual reserves that exceeded 4 months of imports while those that used the import coverage approach tended to have median actual reserves of about 3 months of imports.



Adequate vs. Actual level of reserves, by metric
*(bubble sizes represent number of respondents)*
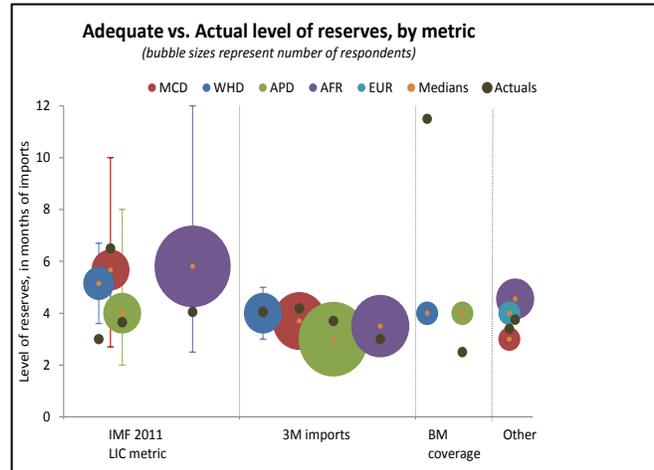
**29.    Survey respondents noted the usefulness of the metric and suggested areas where it could be further improved.** Responses to open-ended questions called for guidance in estimating the marginal cost of holding reserves, noting the lack of data for this estimation and sensitivity of the adequate level of reserves to the assumed cost. Survey respondents also suggested the need to refine the parameters in the marginal benefit regressions to better reflect country heterogeneity, particularly for small states, resource-rich economies, monetary unions and dollarized economies. Specifically, they called for a structured way to adjust existing parameters (e.g., the fiscal balance in RRs) as well as to include new parameters (such as remittances in small islands and oil prices) to better reflect the probability and magnitude of shocks. They noted that equally important in improving the methodology and differentiating the metric across country groupings, such as small states and RRs, would be to propose a cross-country approach to calibrate the unconditional probability of shocks taking into account the heterogeneity of LICs' exposure to exogenous shocks. Some country teams also called for more operational guidance on how to use the metric, and a simple template and a PowerPoint presentation that could guide discussions with the authorities.

**30.    In general, country teams applied judgment in the application of the metric and made changes to the parameters to reflect country heterogeneity**. For example, some RR country teams (e.g., Nigeria) adjusted the fiscal balance parameter to reflect the greater sensitivity of the fiscal stance to oil prices, and some country teams (e.g., Cape Verde) estimated the marginal benefit regression using country-specific data.

**31.    Similar to the findings from a survey of country authorities, the Fund LIC team survey respondents typically used the opportunity cost of holding reserves as the main benchmark for assessing the cost of holding reserves** (Figure 3). A large share of teams assumed that the marginal cost was less than 5 percent. Country teams typically used the marginal product of capital to estimate the opportunity cost of holding reserves but a few used the external and/or domestic funding cost while a sizeable number applied judgment. The motivation for using the choosing the approach was: (i) to capture the difference between the return on assets and capital, with a number of teams noting the increase in public investment or FDI, (ii) reference values based on staff reports,

(iii) availability of data, (iv) to reflect proxies from the literature, and (v) an opportunity cost of foregone risk-free investment.  A survey of country authorities found that the most common approach used by LICs to  estimate the cost of holding reserves was the cost of foregone consumption or investment (this is based on only 5 LICs which responded to this survey—see para 71 in main paper.

**Figure 3. Approaches and Reasons for Estimating the Cost of Holding Reserves**

**Approaches to capture the cost of holding reserves
(Number of responses)**

**Reasons for choosing the approach
(Number of responses)**

Source: Staff Survey

[1] One country team applied two approaches (interest of external debt and domestic debt), and the response is divided by two to reflect the double-entry.

[2] One of the following approaches was used: dollar deposits in the banking system; cost of short-term borrowing for oil imports; spread over US treasury bonds; return on central bank holdings; and quasi-fiscal cost of sterilization.

[3] High investment needs, increase in public investment and/or FDI were cited as important drivers for this approach.