Turning Over a Golden Leaf?
Global Liquidity and Emerging Market Central Banks' Demand for Gold after the Financial Crisis

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Abstract

The quantity of gold reserves held by central banks in emerging markets and developing economies (EMDEs) has risen sharply following the global financial crisis in 2008. This paper examines factors driving holding of gold by central banks in 50 EMDEs using a dynamic panel generalized method of moments model. We find that monetary expansion in advanced economies is robustly related to the post-crisis increase in EMDE gold reserves, after controlling for domestic factors and changes in the global risk environment. This effect holds across different measures of global liquidity, and is robust to alternate model specifications, inclusion of additional covariates, and alternate estimation methods. We argue that the unprecedented monetary expansion in advanced economies has resulted in a shift in EMDE reserve asset holding strategy, resulting in continued accumulation of gold reserves even after the peak of the financial crisis.

Keywords: gold reserves, emerging markets, central banks, monetary easing

JEL Codes: G11, F31, F33

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"The desire of gold is not for gold. It is for the means of freedom and benefit."

- Ralph Waldo Emerson

1. Introduction

The gold holdings of central banks in emerging markets and developing countries (EMDEs[1]) mostly followed a similar trajectory as advanced economies for several decades until the mid-2000s, as gold was gradually supplemented or replaced by a variety of hard currencies such as the U.S. dollar, British pounds, yen, and euro (O'Connor et al, 2015). With the onset of the global financial crisis (GFC) or the Great Recession in 2008, there was a sharp increase in the gold holdings of central banks. This portfolio shift towards gold during the global crisis reflected its status as a safe asset at a time of intense financial turmoil, as has been documented for other "risk-off" periods and crises episodes (Baur & Lucey, 2010; Baur & McDermott, 2010; WGC 2016). Gold as a safe haven asset is attributed to its role as one of the first forms of money that was used traditionally as an inflation hedge, and lack of correlation with other types of assets, an important differentiator in a globalized world where the most of the asset classes are highly correlated (Baur & Lucey, 2010). However, as pointed out by Aizenman & Inoue (2013), in an era when 'plastic money' and 'electronic money' are increasingly accepted as the norm for providing intermediation services, the role of precious commodity metals such as gold in central bank reserves remains a puzzle.

During the post-crisis years, gold holdings of advanced economies fell in tandem with a decline in global risk. However, gold holdings of EMDE central banks have continued to rise in this

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[1] EMDE classification is based on the World Bank country classification. We have considered UMIC, LMIC and LIC income group classification as EMDE countries for the study.

period (figure 1). This sharp increase in the post-crisis period after several decades of relative stability suggests a structural change in EMDE central bank gold holdings. Overall gold reserves of EMDE central banks rose from 129.8 million troy ounces in 2005 to 167 million ounces by the end of 2009, and further to 242.1 million ounces by 2015 – an 86 percent increase from the level in 2005. Statistical analysis using a Markov regime switching test (Hamilton, 1989) indicates a structural break in aggregate EMDE gold holdings during 2009-2015 compared to the previous period (see appendix figure A.1). This aggregate pattern is broadly mirrored at the country level, with some variation across individual countries.

Figure 1: Gold holdings of central banks in emerging markets and developing economies (EMDEs) and advanced economies

Gold holdings (millions troy ounces)
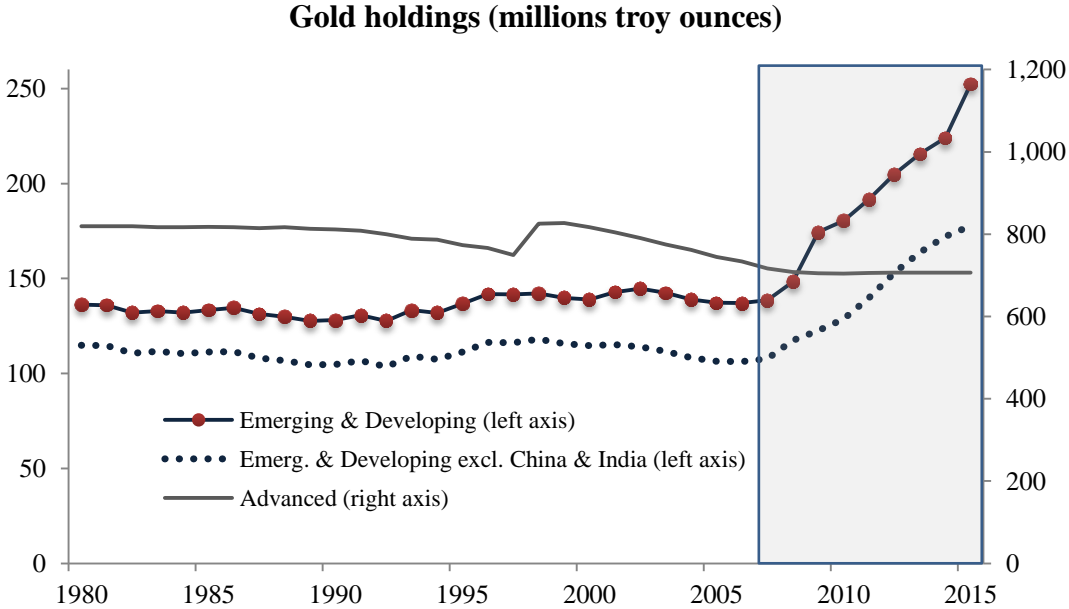
Source: Authors' calculations using IMF IFS database.

The post-financial crisis period was characterized by unprecedented monetary easing in the advanced economies, as central banks in the major G-4 countries (United States, Euro Area, Japan, and the United Kingdom) resorted to a range of conventional and unconventional

monetary policies to limit the effect of the GFC on output and employment (Fawley & Neely, 2013). The unconventionality of the monetary policies implemented by these central banks can be evidenced using a regime switching test, which shows that central bank assets experienced a post-crisis structural break (see Appendix figure A.2). The results indicate a regime change in the way monetary measures have been used to enhance liquidity in the system.

The heads of several EMDE central banks had expressed apprehensions about the spillover effects of these measures by G-4 central banks on their currencies through massive capital inflows, and potential vulnerability to sudden reversals of these flows (Eichengreen, 2013; Rajan, 2015). Some EMDE policymakers deemed it a "currency war"[2] in which advanced economies were trying to undervalue the respective currencies to boost their economic activity, which led to a lack of trust amongst the G-20 nations (Zoellick, 2011). In addition, these measures also acted as a signal to the EMDE central banks on the outlook of the G4 currency denominated assets.

The massive and persistent monetary easing for several years since the GFC likely led to a shift in the reserve accumulation strategy of EMDE central banks away from the so-called hard currencies. As shown in figure 2, the share of gold in EMDE central bank reserves has risen together with a corresponding fall in the share of the G-4 major currencies.[3] Figure 2 provides two estimates of the proportion of G-4 currency reserves to overall reserves (allocated reserves from the COFER database) including gold reserves of the EMDE countries reporting to IMF.

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[2] Guido Mantega, finance minister of Brazil in 2010 publicly asserted that the world was in the midst of an international currency war. https://www.ft.com/content/33ff9624-ca48-11df-a860-00144feab49a

[3] We also observe a sharp increase in the share of other currencies held by EMDE central banks, from about 2 percent of overall reserves in 2008 to 8 percent in 2015. This supports our main hypothesis that EMDE central have diversified *away* from G-4 currencies to gold and other currencies. IMF COFER does not provide disaggregated data on the holding of currencies at the country level; hence, we choose to focus on gold where such country-level data is available from the World Gold Council.

The first estimate (Alt. 1 in figure 2) is based on the gold reserves of those EMDE countries that report their reserve composition to IMF, and the other estimate (Alt. 2) is based on the cumulative gold reserves of all the EMDE central banks. The trends indicate a dramatic shift in the proportion of reserves held as gold and in G-4 currencies after 2008, indicating a significant shift in the way the reserve composition of EMDE central banks has evolved.

Figure 2: Composition of overall EMDE central bank reserves 1999-2015
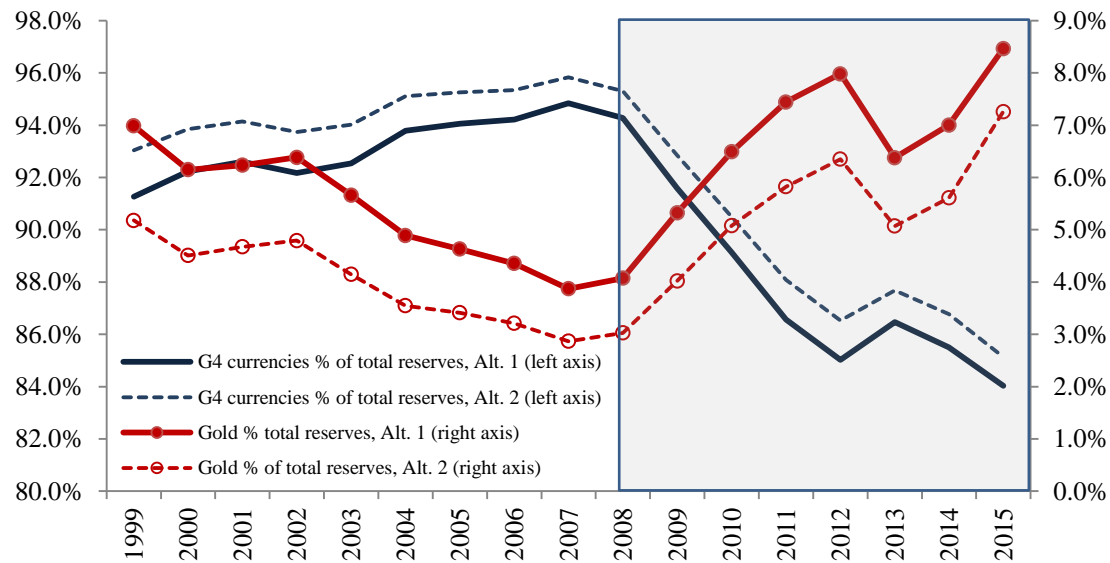
Source: Authors' calculations using IMF COFER database and IMF IFS.
Note: Alt. 1 is a conservative estimate of G-4 currency holdings in overall reserves of EMDEs, and Alt. 2 is a liberal estimate (see text). Currencies other the G-4 currencies account for the remaining part of overall reserves.

In this paper, we empirically investigate whether and how excessive monetary easing in advanced economies, which is largely exogenous to EMDEs, may have influenced the regime shift in gold accumulation by EMDE central banks. In order to estimate this, we use a dynamic panel generalized method of moments model to understand whether excessive monetary easing by the central banks in the advanced economies can explain this increase in EMDE gold reserves, after controlling for domestic factors and changes in the global risk environment. We use several different proxies for studying the impact of this massive loosening in liquidity

conditions on the change in gold reserves composition of EMDE central banks. The results indicate that the monetary easing in advanced economies which followed the GFC played a significant role in the demand for gold reserves by EMDE central banks. We validate our baseline results by conducting robustness checks using different specifications, inclusion of additional covariates and alternate estimation techniques.

This work contributes to the literature in several ways. To our knowledge, this is the first study to analyze the shift in gold accumulation strategy of EMDE central bank after the GFC. Our findings reiterate the role of gold as a safe haven, particularly for EMDE countries due to the perceived policy uncertainty in the post-crisis years. This research complements the work done by Aizenman & Inoue (2013) for advanced economy central banks by looking at EMDE central banks exclusively.

The next section discusses the theoretical background behind shifts in reserve accumulation strategies of EMDE central banks. This is followed by data and methodology in Section 3 and a discussion of results and analysis in Section 4. The subsequent section concludes with some implications for policy.

2. Theoretical background: Role of liquidity in shifts in reserve accumulation strategies of central banks

Coordination problems among economies originate from the asymmetries prevalent in the structures, growth rate and relative cyclical positions of the developed and developing economies (Obstfeld 2013). Greater the cooperation among the competing economies from both developed and developing side, lesser the need for international liquidity to mitigate the imbalances.

According to Obstfeld, a lack of cooperation among the nations has caused excess liquidity to be injected into the IMS post the GFC of 2008, thereby revealing the extent to the imbalances prevalent today.

The dominance of the US dollar in the international monetary system (IMS) as the main reserve currency following the Bretton woods era has perpetuated the so-called Triffin dilemma (Triffin, 1960). The Triffin dilemma in its earlier form was in the context of the Bretton woods agreement of convertibility of US dollar to gold. Obstfeld (2013) draws attention to the reserve holdings status of the central banks of all countries in 1970, which stood at USD 42 billion as against the gold holding of United States, which was USD 11 billion, indicating that the US had to cover the shortfall in claims by buying up more gold should there have been a run at that point in time. The shortfall was such that even if the treasury could purchase all of the official monetary gold and the supply of gold, it would have fallen short; this would have resulted in a potential fiscal insolvency of the US.

The modern day Triffin dilemma discussed by Farhi, Gourinchas, & Rey (2011) argues that the governments in the core of the IMS will have to continue the issuance of gross government debt to satisfy the demand for reserves from the countries in the periphery. The present day dilemma remains even in a multipolar world with several reserve currencies (Obstfeld, 2013). A supplementary problem with this dilemma is that the increasing external debt of the countries' issuing reserve currencies will undermine the confidence of the investors in the reserve asset (Lee, 2014).

Miranda-Agrippino & Rey (2015a) argue that US monetary policy is the primary driver of the global financial cycles and questions the level of independence enjoyed by other central banks,

even those with flexible exchange rates such as the UK or the ECB.[4] Therefore, the massive monetary easing conducted by the advanced economy central banks, led by the US Federal Reserve, have increased the vulnerabilities of the EMDE central banks given the spillover effects on the EMDE countries, evidenced in several studies (Fratzscher, Lo Duca, & Straub, 2016; Lim & Mohapatra, 2016).

Another reason for the shift in reserve accumulation strategy of emerging market economies is the internationalization of some of the currencies that are increasingly considered as reserve currencies and a call for a multipolar IMS. As mentioned in recent literature, China has shown its intent in making its currency fully convertible (Chen & Cheung, 2011; Fratzscher & Mehl, 2014). In the same vein, there is evidence that while the dominance of US dollar continues post-GFC, the pillars supporting that role is waning (Kirshner, 2014). However, there are challenges to full convertibility of yuan since the country is attempting to orchestrate a transition without hampering domestic growth and export growth (Chan, 2017; Lo, 2016). The delay in the convertibility of yuan increases the uncertainty surrounding its potential reserve currency status as well.

The implications of the massive expansion of G-4 central bank balance sheets for future financial stability and risks stemming from a revelation of underlying imbalances can potentially cause a loss of confidence in the existing major reserve currencies. The need for diversification by the EMDE economies stem from these imbalances and the challenges faced by China in making yuan fully convertible. Gold is perceived to be a safe asset during uncertain and highly volatile times, and this characteristic of gold is evidenced in the literature (O'Connor, Lucey, Batten, &

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[4] Miranda-Agrippino & Rey (2015a) find that one global factor in the form of US monetary policy explains an important part of the variance in asset returns across the world.

Baur, 2015). The role of gold in portfolio diversification has been found in many studies (Beckmann, Berger, & Czudaj, 2015; Bredin, Conlon, & Poti, 2015) and policy makers have called for active management of gold in central bank portfolio to help in diversification (European Central Bank, 2004). Given the benefits offered by gold, EMDE central banks have resorted to an accumulation of gold reserves to hedge the potential risks that are prevalent in the IMS since the GFC.

3. Data and Methodology

3.1 Data description

An annual database of EMDE central banks' gold reserves and the other global as well as country-specific variables was constructed. The EMDE gold reserves data was from the IMF International Financial Statistics (IFS) database. All the other variables were obtained from the World Development Indicators (WDI), IMF International Financial Statistics, Chicago Board of Options Exchange (CBOE) database, Federal Reserve Bank of St. Louis database (FRED), and World Bank International debt statistics (see Appendix table A.1 for variable description and sources). Appendix table A.2 presents the list of 50 EMDE countries in our sample, and appendix table A.3 presents pairwise correlations among the variables.

Liquidity indicators can be broadly classified as price based and quantity based indicators (Adrian & Shin, 2009). Among quantity based indicators, the conventional measure of liquidity is the monetary aggregate of the advanced economies (Belke, Bordon, & Volz, 2013; Chung, Lee, Loukoianova, Park, & Shin, 2015) which is considered the core liquidity measure. The other quantity indicator that has gained importance post the global financial crisis is the credit

based aggregates that is accounted by the official liquidity, which is created by the central banks through both conventional and unconventional measures, and the private liquidity created by financial institutions (Committee on the Global Financial System, 2011). Conventional price based indicator of liquidity is the short term interest rate of the advanced economies (Adrian & Shin, 2009).

As a measure of this liquidity, the variables used for the analysis include a Global Liquidity Measure (GLM), G-4 central bank asset holding (G4CB)[5], GDP-weighted short-term rate (STR) of the advanced economies, and US treasury purchases (USLM). GLM is taken in constant dollars as well as in real terms as indicated below:

$$GLMC_{it} = \Sigma_i \left(\frac{MA_{it}}{LCU\_USD\_2010_{it}} \right) \tag{1}$$

$$GLMR_{it} = \Sigma_i \left(\frac{MA_{it}}{LCU\_USD\_2010_{it}} \frac{P_{2010}}{P_t} \right) \tag{2}$$

where *i* refers to the country under study in time period *t* and *MA* refers to monetary aggregate in local currency units, *LCU_USD_2010* is the currency conversion to 2010 US dollars and *P* is the CPI in the respective year. *GLMC* and *GLMR* refer to the liquidity measure in US dollars at constant 2010 exchange rates and in real (inflation-adjusted) local currency converted to US dollars at constant exchange rate. These variables account for fluctuations in monetary aggregates that may arise from exchange rate fluctuations among the major currencies, as well as from domestic inflation. A similar method is used to arrive at the aggregate central banking

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[5] The G-4 advanced economies comprise the Euro Area (19 countries), Japan, United States, and the United Kingdom

assets of the G-4 advanced economies (*G4CBC and G4CBR*) in constant USD and real USD terms respectively. Descriptive statistics for these liquidity measures are presented in table 1.

Global risk has been recognized as a determinant of the gold holdings of central banks in a study done by Gopalakrishnan & Mohapatra (2017). Global risk is also considered to be driving the global financial cycle (Miranda-Agrippino & Rey, 2015b). VIX index, a measure of risk used in the literature to indicate global uncertainty, is used in this study to capture global risk component (Garcia, Ortiz, & Cowan, 2006; Jubinski, Lipton, & Joseph, 2013).

Table 1: Descriptive statistics

Variable	Mean	Std. Dev.	Min	Max
Global				
Log of GLMC	31.0163	0.2606	30.5757	31.3928
Log of GLMR	30.9949	0.2934	30.5131	31.4338
Log of G4CBC	29.2468	0.4918	28.5863	30.1475
Log of G4CBR	29.2739	0.4341	28.7200	30.0828
GDP-weighted short term rate (%)	2.29889	1.6696	0.2501	5.7628
TED Spread (%)	0.49706	0.3514	0.1900	1.5500
Log of US treasury purchases real	20.9301	0.8069	19.998	22.2493
VIX index	21.4135	6.1247	12.800	32.690
USD appreciation	0.0018	0.0477	-0.0596	0.1258
Country-specific				
Gold reserves as share of GDP (%)	0.97601	1.2564	0.0000	8.9693
GDP growth (%)	4.38768	4.0404	-14.759	55.556
Trade openness to GDP (%)	76.8406	35.292	15.4195	220.230
Capital Account openness	41.1635	32.036	0.0000	100.000
Private credit to GDP (%)	37.1183	31.023	1.2669	160.1250
Log of GDP per capita	7.55858	1.0642	4.6636	9.6514
Log of IIR	3.51577	0.4780	1.6864	4.3845
CPI Inflation (%)	9.08952	16.627	-72.729	293.733
Log of Gold price (Const. 2010 USD)	6.51601	0.5384	5.8462	7.34709
External debt to GDP (%)	50.3781	33.824	4.0807	260.482
Inflation volatility	0.00925	0.0214	0.0000	0.3998

The country-specific determinants of gold reserves include capital account openness, trade openness, GDP per capita, GDP growth, external debt to GDP, the ratio of private credit to GDP, gold price (in 2010 US dollars), Institutional Investor Risk (IIR) index, inflation and

inflation volatility. Higher capital account openness usually increases the vulnerability of the country to sudden changes in gross capital flows (Roveda & Rosselli, 2003). Both capital account openness and trade openness are measures used as determinants of central bank reserve holdings in previous studies (Lane & Burke, 2001; Marc-Andre & Parent, 2005; Obstfeld, Shambaugh, & Taylor, 2009). GDP per capita is a proxy for economic size, which is one of the determinants of the overall reserves. GDP growth factors in the propensity to accumulate gold reserves and also controls for the strategic initiatives by many countries to ensure consistent growth (Aizenman & Lee, 2008; Benigno & Fornaro, 2012; Cheng, 2015).

Private credit to GDP, an indicator for financial development (Svirydzenka, 2016), has been used as one of the determinants of reserve holdings by central banks (Lane & Burke, 2001). Institutional Investors Rating (IIR) is used as a proxy for country-specific risk perceptions. Inflation and foreign currency debt are considered to affect the overall gold holdings of a central bank (Aizenman & Inoue, 2013). Gold price in real terms is used to control for the effect on the value of gold reserves, however, we also evaluate the baseline regressions without gold price in the robustness section. The last control variable added to the baseline specification is the US dollar appreciation (computed from the US dollar index against a basket of its trading partners). It is well documented that the commodity prices are inversely related to the US dollar (Akram, 2009; Hammoudeh, Nguyen, & Sousa, 2015).

3.2. Methodology

The specification for the determinants of gold holdings by emerging market central banks can be expressed as:

$$G_{it} = \gamma G_{it-1} + \beta GLM_t + \mathbf{Z}'_t\boldsymbol{\delta} + \mathbf{X}'_{i,t}\boldsymbol{\theta} + \mu_i + \varepsilon_{it} \qquad (3)$$

where *G* is gold reserves as a share of GDP in EMDE countries, *GLM* is the global liquidity measure which is based on monetary policy measures in advanced economies, $\mathbf{Z}$ is a vector of global factors other than GLM, $\mathbf{X}$ is a vector of macroeconomic and institutional variables at the country-level, μ_i is a country-specific intercept, and $\varepsilon_{it} \sim N(0, \sigma^2)$ is an i.i.d error term.

As discussed in the earlier section, the vector of global variables includes VIX, international gold price (in 2010 US dollars), and US dollar appreciation. The country-specific variables include capital account openness, trade openness, GDP per capita, GDP growth, IIR country ratings, gold price, inflation, private credit to GDP, foreign currency external debt to GDP, and inflation volatility. In some alternate specifications, we bring in TED spread, net portfolio flow volatility and long term yields as additional covariates. Summary statistics are shown in table 2.

It has been evidenced that the coefficients obtained from ordinary least squares with fixed effects are prone to dynamic panel bias (Nickell, 1981) in cases where one of the explanatory variables has a lag of the dependent variable. We control for this bias using a dynamic panel generalized method of moments (GMM) estimators. The estimator used in this study is the Systems GMM (SGMM) estimator of Arellano & Bover (1995), which is suitable for datasets with lower time periods and a larger number of entities under study. SGMM uses the first difference and level residuals of the estimate for the moment conditions and is considered efficient given the flexibility in the use of instruments (Roodman, 2009).

Another econometric issue that we foresee in the specification is the potential endogeneity of some of the explanatory variables to central banks' gold holding and these issues are

acknowledged in related literature such as Bussière, Cheng, Chinn, & Lisack (2015) for GDP growth, Baur (2016) for gold price, capital account openness, and IIR. This issue is mitigated by using the SGMM estimator which permits and accounts for potential endogenous variables. Moreover, we use one period lagged explanatory variable to avoid contemporaneous feedback effects.

4. Results

4.1 Baseline results

We analyze the effect of liquidity measures undertaken by advanced economy central banks using two global liquidity measures (GLM) as indicated in the earlier section: GLMC and GLMR[6]. This measure of liquidity, based on monetary aggregates, is the conventional measure of liquidity used in a lot of studies. The results obtained from the dynamic panel regression method are as shown in table 2 below. In order to understand the impact of the unconventional monetary measures, the estimations were done using the overall sample period (1999 to 2015) and two sub-periods (1999-2007 and 2008 to 2015) to identify the effect of the structural change in the responsiveness to the unconventional monetary measures.

The overall results using the GLMC and GLMR measures are as shown in columns (1) and (4) of table 2, and the sensitivity of the gold holdings of EMDE central banks are positive and significant to the GLM measures after controlling for other factors, both domestic and global, that determine the accumulation of gold reserves. This effect is larger since 2008 (columns (3)

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[6] A bivariate analysis of the median gold holdings (gold_to_gdp) and the GLMR is as shown in appendix figures A.3.

and (6)) indicating a shift in the accumulation strategy from then on and coincides with the liquidity loosening undertaken by the advanced economies.

The results of the period until 2007 in columns (2) and (5) of table 2 indicate that there was hardly any significant relationship between the liquidity measures and gold accumulation of the EMDE central banks. Sensitivity of gold accumulation to global liquidity for the entire time period, which is positive and significant, is driven by the changes in gold accumulation post 2008 with no significant effect from pre-crisis period.

In addition to the GLM measures, we evaluate the role of the central bank assets in the G4 countries as a proxy for the excess liquidity and its effect on the gold accumulation of the EMDE central banks. The results are as shown below in table 3. The sensitivities of gold holdings to this measure both in constant USD (G4CBC) and real USD terms (G4CBR) is consistent with the earlier results for GLM.

As evidenced in table 3, the effect of liquidity is not significant pre-2008 and the overall results are driven by the post crisis developments for the period starting 2008 (columns (3) and (6)). The post 2008 sensitivity of the gold reserves is higher for GLMR measure of liquidity than the G4CBR measure. The results obtained in this analysis substantiate the role of monetary easing, conducted by G4 central banks through multiple channels, in determining the gold holdings of EMDE central banks.

Table 2: Global liquidity and central bank gold reserves in EMDEs

	Global liquidity measure – const. USD (GLMC)			Global liquidity measure – Real (GLMR)		
	Full sample (1)	Pre-2008 sample (2)	Post-2008 sample (3)	Full sample (4)	Pre-2008 sample (5)	Post-2008 sample (6)
Gold to GDP$_{t-1}$	0.983***	0.990***	0.874***	0.851***	0.936***	0.946***
	(0.116)	(0.099)	(0.157)	(0.085)	(0.085)	(0.142)
Log GLMC$_{t-1}$	1.341**	0.362	2.811***			
	(0.528)	(0.362)	(0.787)			
Log GLMR$_{t-1}$				1.382**	0.483	5.245***
				(0.631)	(0.584)	(1.312)
VIX$_{t-1}$	0.014***	-0.006	0.030***	0.011***	-0.005	0.027***
	(0.003)	(0.004)	(0.009)	(0.003)	(0.004)	(0.007)
USD appreciation$_{t-1}$	-0.916**	1.394***	-4.324***	-0.740**	1.431***	-4.202***
	(0.372)	(0.465)	(1.051)	(0.369)	(0.503)	(1.021)
GDP growth$_{t-1}$	-0.01	0.019	-0.032**	-0.011	0.023	-0.026*
	(0.012)	(0.018)	(0.015)	(0.012)	(0.020)	(0.014)
Trade openness$_{t-1}$	-0.005	-0.004**	-0.004	-0.004	-0.005*	-0.004
	(0.004)	(0.002)	(0.003)	(0.004)	(0.003)	(0.004)
KAOPEN$_{t-1}$	0.001	0.005**	-0.001	0.001	0.005*	-0.001
	(0.002)	(0.002)	(0.005)	(0.002)	(0.003)	(0.004)
Private credit to GDP$_{t-1}$	-0.001	0.004	-0.004	0.000	0.004	-0.005
	(0.003)	(0.003)	(0.005)	(0.003)	(0.004)	(0.004)
Log GDP per capita$_{t-1}$	-0.18	0.027	-0.119	-0.068	0.021	0.044
	(0.133)	(0.099)	(0.280)	(0.120)	(0.126)	(0.298)
Log IIR$_{t-1}$	0.284	-0.257	0.169	0.166	-0.23	0.044
	(0.263)	(0.223)	(0.532)	(0.202)	(0.244)	(0.481)
Inflation$_{t-1}$	-0.001	-0.001	-0.02	0.000	0.000	-0.012
	(0.004)	(0.004)	(0.016)	(0.004)	(0.005)	(0.013)
Log Gold price$_{t-1}$	-0.518**	-0.158	-0.650*	-0.342*	-0.116	-0.833***
	(0.238)	(0.158)	(0.349)	(0.184)	(0.168)	(0.301)
Debt to GDP$_{t-1}$	0.000	-0.001	0.004	0.000	-0.001	0.004
	(0.001)	(0.002)	(0.006)	(0.001)	(0.002)	(0.005)
Inflation Vol$_{t-1}$	-6.746	7.033	-5.896	-5.239	7.446	-5.159***
	(6.263)	(10.278)	(6.118)	(4.741)	(8.328)	(1.767)
Constant	-37.693***	-9.449	-82.713***	-40.563**	-13.523	-158.255***
	(14.577)	(10.043)	(23.685)	(18.059)	(16.772)	(40.330)
Country fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs. (countries)	667 (50)	335 (50)	332 (50)	667 (50)	335 (50)	332 (50)
No. of instruments	52	39	44	55	40	44
Hansen statistic	43.159	26.788	36.435	42.744	27.446	33.402
AR(2) statistic	-0.553	-0.513	-1.519	-0.648	-0.556	-1.19
Wald Chi-square	656.489	673.48	155.909	842.482	668.615	173.47

Notes: The dependent variable is central bank gold reserves as a percentage of GDP for EMDE countries. GLMC is the global liquidity measure at constant 2010 exchange rates. GLMR is the global liquidity measure in real (inflation-adjusted) terms and at constant 2010 exchange rates. Standard errors presented below the coefficient estimates in parenthesis are Windmeijer corrected and clustered at the country level. *** Significant at 1%, ** significant at 5% and * significant at 10%. All the SGMM regressions pass the Hansen test of over-identifying restrictions and the test for second-order autocorrelation suggesting that the SGMM moment conditions are not violated.

Table 3: Central bank assets of G-4 advanced economies and gold reserves in EMDEs

	G-4 Central bank assets - const. USD (G4CBC)			G-4 Central bank assets - Real (G4CBR)		
	All years (1)	Pre-2008 sample (2)	Post-2008 sample (3)	All years (4)	Pre-2008 sample (5)	Post-2008 sample (6)
Gold to GDP$_{t-1}$	0.840***	0.949***	0.927***	0.819***	0.949***	0.922***
	(0.079)	(0.088)	(0.157)	(0.070)	(0.088)	(0.163)
Log G4CBC$_{t-1}$	0.285*	-0.027	1.030***			
	(0.154)	(0.193)	(0.240)			
Log G4CBR$_{t-1}$				0.329**	-0.066	1.170***
				(0.151)	(0.221)	(0.269)
VIX $_{t-1}$	0.014***	-0.006	0.033***	0.014***	-0.005	0.032***
	(0.003)	(0.004)	(0.007)	(0.003)	(0.003)	(0.007)
USD appreciation$_{t-1}$	-0.792*	1.425***	-4.307***	-0.802*	1.435***	-4.410***
	(0.408)	(0.509)	(0.945)	(0.430)	(0.508)	(0.937)
Log Gold price$_{t-1}$	-0.068	0.037	-1.002***	-0.069	0.055	-1.031***
	(0.120)	(0.133)	(0.326)	(0.112)	(0.132)	(0.339)
Country controls	Yes	Yes	Yes	Yes	Yes	Yes
Country fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs. (countries)	667 (50)	335 (50)	332 (50)	667 (50)	335 (50)	332 (50)
No. of instruments	57	40	44	53	40	44
Hansen statistic	39.869	26.299	35.654	37.195	26.379	35.727
AR(2) statistic	-0.855	-0.63	-1.067	-0.84	-0.652	-1.057
Wald Chi-square	862.877	633.729	171.576	1027.036	649.342	170.153

Notes: The dependent variable is central bank gold reserves as a percentage of GDP for EMDE countries. G4CBC is the combined central bank assets in the G-4 advanced economies (Euro Area, Japan, United States, and the United Kingdom) at constant 2010 exchange rates. G4CBR is the combined central assets of G-4 economies in real (inflation-adjusted) terms and at constant 2010 exchange rates. Standard errors presented below the coefficient estimates in parenthesis are Windmeijer corrected and clustered at the country level. *** Significant at 1%, ** significant at 5% and * significant at 10%. All the SGMM regressions pass the Hansen test of over-identifying restrictions and the test for second-order autocorrelation suggesting that the SGMM moment conditions are not violated.

4.2 Alternate measures of global liquidity

In this section, we estimate the above baseline specification using alternate measures of liquidity other than the GLM and G4CB variables. The variables used in the analysis are a US liquidity measure, which is the cumulative treasury purchases (in real 2010 US dollars) by the US Federal Reserve since 2002, and the GDP-weighted short-term interest rate of the advanced economies. The use of alternative measures helps us in verifying our findings for the global measure and

whether the measures undertaken by the leading advanced economies such as the United States are in line with the overall results.

The results of this analysis are as shown in columns (1), (2) and (3) of table 4. The finding here is that there is an increase in the sensitivity of gold holdings of EMDE central banks since 2008 when the US Federal Reserve decided to start the large-scale asset purchase (LSAP) programs to improve the liquidity in the system. The findings for the U.S liquidity measure are similar to the global liquidity measure with the sensitivity being positive and significant post crisis and in the same order of magnitude as the cumulative G4CBR.

Table 4: Alternative measures of global liquidity

	US Liquidity Measure (USLM)			Short-term interest rates (STR)		
	All years (1)	Pre-2008 sample (2)	Post-2008 sample (3)	All years (4)	Pre-2008 sample (5)	Post-2008 sample (6)
Gold to GDP$_{t-1}$	0.811***	0.908***	0.900***	0.814***	0.952***	0.887***
	(0.086)	(0.096)	(0.153)	(0.071)	(0.060)	(0.124)
Log USLM$_{t-1}$	0.048	-0.165	0.457**	-0.011	-0.003	-0.194***
	(0.049)	(0.118)	(0.221)	(0.011)	(0.011)	(0.048)
STR$_{t-1}$				-0.021*	0.002	-0.114**
				(0.013)	(0.012)	(0.044)
VIX$_{t-1}$	0.013***	-0.004	0.039***	0.011***	-0.010**	0.011**
	(0.004)	(0.004)	(0.012)	(0.004)	(0.004)	(0.005)
USD appreciation$_{t-1}$	-0.811	0.92	-3.453***	-0.503	0.767**	-3.435***
	(0.513)	(0.657)	(0.853)	(0.361)	(0.329)	(0.829)
Log Gold price$_{t-1}$	0.134	0.156	-0.974**	-0.047	-0.029	-0.922**
	(0.084)	(0.130)	(0.409)	(0.106)	(0.121)	(0.364)
Country controls	Yes	Yes	Yes	Yes	Yes	Yes
Country fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs. (countries)	545 (50)	213 (50)	332 (50)	706 (50)	374 (50)	332 (50)
No. of instruments	50	36	44	51	44	46
Hansen statistic	38.537	17	28.746	41.123	33.615	38.013
AR(2) statistic	-0.763	-0.476	-0.466	-1.119	-0.648	-1.197
Wald Chi-square	520.011	1160.855	266.811	1225.343	2195.493	316.349

Notes: The dependent variable is central bank gold reserves as a percentage of GDP for EMDE countries. USLM is the liquidity measure for the United States in real (inflation-adjusted) terms and at constant 2010 exchange rates. STR is the weighted-average of short-term interest rates in the G-4 advanced economies. Standard errors presented below the coefficient estimates in parenthesis are Windmeijer corrected and clustered at the country level.*** Significant at 1%, ** significant at 5% and * significant at 10%. All the SGMM regressions pass the Hansen test of over-identifying restrictions and the test for second-order autocorrelation suggesting that the SGMM moment conditions are not violated.

Next, we estimate the baseline results using a GDP-weighted short-term rate measure for the countries that were used to arrive at GLM. This is a price indicator of liquidity in the system and the advanced economy central banks have consistently reduced the base rates since the crisis going to zero lower bounds and in the case of some countries, going beyond the zero lower bounds to negative interest rate territories.

As indicated in columns (4), (5) and (6) in table 4, the results indicate that the gold holdings in EMDE central banks have risen in response to lowering short-term rates across the advanced countries. This is consistent with the results we obtained in terms of monetary aggregates and central bank asset holdings.

4.3 Robustness tests

In the initial set of robustness checks, we test the consistency of the results after adding additional covariates. One of the possibilities is that the sudden capital flows and stops due to the advanced economy central bank decisions would have made the portfolio flows into the EMDE countries more volatile. We control for this by taking the volatility of portfolio flows for the preceding three years as an explanatory variable. The results in table 5, columns (1)-(3), are consistent with the baseline results.

Next, we test whether the addition of TED spread as a proxy for global risk in addition to VIX (columns (4)-(6) of table 5) or if the addition of long-term US yield, a proxy for long-term rates in the advanced countries (columns (7)-(9)), affects our baseline estimations. The results indicating a stronger relationship between global liquidity and EMDE central bank gold holdings in the post-crisis period are consistent with our baseline model.

Table 5: Global liquidity measure (GLMR) with additional covariates

	With Net Portfolio flow volatility (Overall)	With Net Portfolio flow volatility (Pre-2008)	With Net Portfolio flow volatility (Post-2008)	With TED Spread (overall)	With TED Spread (Pre-2008)	With TED Spread (Post-2008)	With US 10 year yield (Overall)	With US 10 year yield (Pre-2008)	With US 10 year yield (Post-2008)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Gold to GDP$_{t-1}$	0.880***	0.935***	0.957***	0.876***	0.954***	0.905***	0.929***	0.982***	0.975***
	(0.110)	(0.046)	(0.101)	(0.096)	(0.114)	(0.127)	(0.088)	(0.094)	(0.156)
Log GLMR$_{t-1}$	1.724***	0.65	4.762***	1.359**	-0.318	5.078***	1.845***	0.719	5.462**
	(0.659)	(0.460)	(1.457)	(0.678)	(1.030)	(1.436)	(0.629)	(1.549)	(2.527)
VIX$_{t-1}$	0.015***	-0.005	0.032***	0.013***	-0.006	0.032***	0.011***	-0.004	0.031***
	(0.004)	(0.003)	(0.008)	(0.003)	(0.005)	(0.008)	(0.003)	(0.006)	(0.008)
USD appreciation$_{t-1}$	-0.723*	1.332***	-3.699***	-0.63	1.475*	-3.912***	-0.905**	1.13	-3.863*
	(0.410)	(0.473)	(1.020)	(0.387)	(0.827)	(1.084)	(0.457)	(0.826)	(2.320)
Log NPFV$_{t-1}$	0.012	-0.025	0.044						
	(0.023)	(0.021)	(0.061)						
TED spread$_{t-1}$				0.025	-0.077	-0.183			
				(0.040)	(0.211)	(0.188)			
US 10 year treasury yield$_{t-1}$							0.127***	0.016	0.085
							(0.039)	(0.087)	(0.318)
Log Gold price$_{t-1}$	-0.367*	-0.244	-0.905***	-0.361*	0.088	-0.841**	-0.195	-0.198	-0.805
	(0.199)	(0.188)	(0.350)	(0.214)	(0.286)	(0.336)	(0.173)	(0.400)	(0.695)
Country controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs. (countries)	590(46)	287(46)	303(46)	667 (50)	335(50)	332(50)	667 (50)	335(50)	332(50)
No. of instruments	49	37	44	57	45	47	53	41	45
Hansen statistic	35.651	23.358	34.42	42.315	28.954	40.011	38.027	25.765	30.583
AR(2) statistic	-0.083	-0.532	-1.553	-0.692	-0.727	-1.424	-0.783	-0.558	-0.796
Wald Chi-square	458.128	1282.393	260.581	1182.855	488.157	224.396	807.591	531.475	292.888

Notes: The dependent variable is central bank gold reserves as a percentage of GDP for EMDE countries. GLMR is the global liquidity measure in real (inflation-adjusted) terms and at constant 2010 exchange rates. Standard errors presented below the coefficient estimates in parenthesis are Windmeijer corrected and clustered at the country level. *** Significant at 1%, ** significant at 5% and * significant at 10%. All the SGMM regressions pass the Hansen test of over-identifying restrictions and the test for second-order autocorrelation suggesting that the SGMM moment conditions are not violated.

In addition, we check the robustness of the results using the following subsample and alternate specifications. We exclude the five BRICS (Brazil, Russia, India, China and South Africa) nations from the analysis and see if the results are consistent for the rest of the developing countries. The results as shown in in table 6 columns (1), (2) and (3) indicate that the results are consistent with the baseline results with full sample. Although the coefficient for post-crisis period is lower than the full sample indicating a relatively lower sensitivity of non-BRICS countries to global liquidity measures, the results suggest that central banks in other developing nations have also shifted towards the accumulation of gold post-crisis.

In the next set of robustness checks, we estimate the results by removing gold price from the specification (as shown in columns (4) to (6) of table 6) and treat VIX as an endogenous variable (as shown in columns (7) to (9)). Although central banks account for a relatively small fraction of overall global gold demand, it is possible that changes in central bank gold reserve holdings may influence international gold prices at the margin. The direction of the sensitivity and the significance levels of the GLM measure for the post-crisis period are consistent with the baseline results.

The final robustness test that we do is to construct an alternative GLMR measure including the BRICS countries' monetary aggregates. We treat this measure as endogenous in the specification and analyze the sensitivity of this measure. The results (see columns (10) to (12)) indicate that the sensitivity for the post-crisis period is statistically significant and is in the hypothesized direction.

Table 6: Global liquidity measure (GLMR) with subsamples and alternate specifications

	Excl. BRICS All years (1)	Excl. BRICS Pre-2008 (2)	Excl. BRICS Post-2008 (3)	Without Gold Price All years (4)	Without Gold Price Pre-2008 (5)	Without Gold Price Post-2008 (6)	With VIX as endog. All years (7)	With VIX as endog. Pre-2008 (8)	With VIX as endog. Post-2008 (9)	GLM with BRICS monetary aggregates All year (10)	GLM with BRICS monetary aggregates Pre-2008 (11)	GLM with BRICS monetary aggregates Post-2008 (12)
Gold to GDP$_{t-1}$	0.808***	0.973***	0.885***	0.866***	0.932***	0.751***	0.994***	0.995***	0.898***	0.899***	0.943***	0.900***
	(0.098)	(0.062)	(0.105)	(0.070)	(0.083)	(0.132)	(0.102)	(0.060)	(0.132)	(0.093)	(0.060)	(0.134)
Log GLMR$_{t-1}$	1.444**	0.348	3.944***	0.620**	0.103	2.787**	1.449**	0.443	4.545***	1.173**	0.089	2.553***
	(0.640)	(0.468)	(0.964)	(0.241)	(0.377)	(1.321)	(0.596)	(0.382)	(1.246)	(0.473)	(0.360)	(0.753)
VIX$_{t-1}$	0.014***	-0.006	0.031***	0.012***	-0.005*	0.022***	0.009***	-0.006**	0.030***	0.017***	-0.005*	0.037***
	(0.004)	(0.004)	(0.008)	(0.003)	(0.003)	(0.007)	(0.003)	(0.003)	(0.007)	(0.004)	(0.003)	(0.009)
USD appreciation$_{t-1}$	-0.705*	1.377***	-3.508***	-0.352	1.461***	-3.229***	-0.417	1.426***	-4.089***	-0.935**	1.532***	-3.557***
	(0.395)	(0.502)	(0.804)	(0.364)	(0.429)	(0.888)	(0.327)	(0.430)	(0.997)	(0.406)	(0.451)	(0.993)
Log Gold price$_{t-1}$	-0.342*	-0.128	-0.692**				-0.362*	-0.078	-0.938***	-0.499**	-0.131	-0.945**
	(0.176)	(0.186)	(0.271)				(0.201)	(0.122)	(0.353)	(0.198)	(0.210)	(0.424)
Country controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs. (countries)	592 (50)	295 (50)	297 (50)	667 (50)	335(50)	332(50)	667 (50)	335 (50)	332 (50)	667 (50)	335 (50)	332 (50)
No. of instruments	52	39	42	50	38	43	54	38	45	51	42	47
Hansen statistic	39.338	30.012	35.354	42.124	26.777	27.225	41.093	26.154	35.681	43.319	30.467	38.674
AR(2) statistic	-0.53	-0.594	-1.433	-0.843	-0.513	-1.935	-0.596	-0.563	-1.02	-0.329	-0.527	-1.437
Wald Chi-square	712.683	582.003	286.177	767.532	548.78	267.963	544.739	813.039	238.205	443.483	1343.283	323.456

Notes: The dependent variable is central bank gold reserves as a percentage of GDP for EMDE countries. GLMR is the global liquidity measure in real (inflation-adjusted) terms and at constant 2010 exchange rates. Standard errors presented below the coefficient estimates in parenthesis are Windmeijer corrected and clustered at the country level. *** Significant at 1%, ** significant at 5% and * significant at 10%. All the SGMM regressions pass the Hansen test of over-identifying restrictions and the test for second-order autocorrelation suggesting that the SGMM moment conditions are not violated.

Finally we check the robustness of the results with alternative estimation techniques. The results obtained using the Driscoll & Kraay (1998) technique, where the standard errors are heteroskedasticity-consistent as well as control for cross-sectional dependence, is in the hypothesized direction for the post crisis period (see table 7, columns (1) to (3)). The last test in this section uses a bias corrected estimation technique in which the initialization is done using an Anderson & Hsiao (1982) estimator. The results obtained support the post crisis dependence of gold reserves on the global liquidity measure (see columns (4) to (6)).

Table 7: Global liquidity measure (GLMR) with alternate estimation techniques

	Driscoll Kraay All years (1)	Driscoll Kraay Pre-2008 (2)	Driscoll Kraay Post-2008 (3)	Bias corrected LSDV All years (4)	Bias corrected LSDV Pre-2008 (5)	Bias corrected LSDV Post-2008 (6)
Gold to GDP$_{t-1}$				0.675***	0.714***	0.522***
				(0.031)	(0.053)	(0.051)
Log GLMR$_{t-1}$	-0.256	0.095	2.749**	0.644*	0.023	3.710***
	(0.516)	(0.208)	(1.299)	(0.344)	(0.421)	(1.121)
VIX$_{t-1}$	0.010*	-0.003	0.022***	0.014***	-0.001	0.026***
	(0.005)	(0.005)	(0.003)	(0.002)	(0.005)	(0.004)
USD appreciation$_{t-1}$	-0.392	1.319***	-3.593***	-0.614	1.241	-3.285***
	(1.069)	(0.128)	(0.934)	(0.383)	(0.501)	(0.794)
Log Gold price$_{t-1}$	0.722***	0.353**	0.707***	-0.074	0.105	-0.045
	(0.179)	(0.168)	(0.120)	(0.112)	(0.218)	(0.182)
Country controls	Yes	Yes	Yes	Yes	Yes	Yes
Country fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs. (countries)	667 (50)	335(50)	332(50)	667 (50)	335 (50)	332 (50)

Notes: The dependent variable is central bank gold reserves as a percentage of GDP for EMDE countries. GLMR is the global liquidity measure in real (inflation-adjusted) terms and at constant 2010 exchange rates. Standard errors presented below the coefficient estimates in parenthesis are heteroskedasticity consistent and for Driscoll Kraay it is controlled for cross correlation dependence as well. Bias corrected least square dummy variable estimation is initialized using an Anderson Hsiao estimator. *** Significant at 1%, ** significant at 5% and * significant at 10%.

5. Conclusion

This study has examined the correlates of gold reserve accumulation by central banks of emerging markets and developing economies in the years before and after the GFC. After several years of relative stability, EMDE central bank gold reserves rose sharply during the financial

crisis and continued to increase well after the peak of the crisis. We find that the increase in EMDE gold holdings in the post-crisis period was strongly associated with the large expansion in liquidity and increase in central bank balance sheets in the advanced economies. This post-crisis effect holds even after controlling for a range of country-specific factors, international gold prices and global risk. The baseline results are robust to alternative specifications, inclusion of additional controls and alternative estimation techniques.

We view our findings as contributing to the debates on the design of the global financial architecture in the era of global imbalances, quantitative easing, and a massive expansion in the balance sheets of the major central banks in the advanced economies in the years following the GFC. Even though the US dollar continues to maintain its status as the primary global reserve currency in the post-crisis period, the lack of credible alternatives after nearly two decades following the introduction of the euro in 1999 and the uncertainties associated with the efforts at internationalization of the Chinese yuan leave EMDE central bank portfolio managers with a Hobson's choice. The sharp increase in the demand for gold – and a parallel shift away from the major G-4 currencies – by EMDE central banks in the post-crisis period should be seen in the broader context of the possible risks to financial stability and the potential for revelation of underlying imbalances that may result from the extraordinarily loose monetary policies implemented in the advanced economies for several years after the crisis.

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Appendix Table A.1: Data definitions and sources

Variable	Definition and Construction	Data sources
Gold reserves to GDP	Ratio of central bank gold reserves to GDP (both values in current US dollars)	IMF International Financial Statistics (IFS)
Global Liquidity Measure (GLMC)	This is a measure computed using the M2 supply for US and Japan and M3 supply for the rest of the advanced economies, in constant 2010 exchange rates (see text).	FRED, IMF IFS, OECD currency rates
Global Liquidity Measure (GLMR)	GLMC in constant inflation-adjusted real terms (see text).	FRED, IMF IFS, OECD currency rates
G4 central bank assets (G4CBC)	This is a measure computed using the G4 central bank assets, in constant 2010 exchange rates (see text).	FRED, IMF IFS, OECD currency rates
G4 central bank assets (G4CBR)	G4CBC in constant inflation-adjusted real terms (see text).	FRED, IMF IFS, OECD currency rates
US Liquidity Measure (USLM)	Continuous measure of the US FED purchase of treasury assets, mortgaged backed securities and federal agency debt	FRED
Advanced Economy Short term rate (STR)	GDP-weighted benchmark policy rates of all the advanced economies.	IMF IFS
VIX	Index of implied volatility of S&P 500 options - a measure of global risk perception	Chicago Board Options Exchange (CBOE)
USD appreciation	US dollar appreciation based on the dollar index, which is weighted average of the foreign exchange value of the dollar against a broad group of US trading partners	FRED
TED spread	The spread between interbank loans and the US government treasury bills.	FRED
GDP per capita	Gross domestic product per capita in nominal US dollars	World Development Indicators(WDI)
GDP growth	Annual growth of Gross Domestic Product of a country	IMF IFS
Institutional Investor Rating	Institutional investor perception of the sovereign default risk	Institutional Investor rating index
Developing & High Income countries	Country classification based on income.	World Bank classification
Private credit to GDP	Domestic credit to private sector as a share of GDP	WDI
Capital account openness	Measure of the openness of the capital account to foreign fund flows	Chinn and Ito (Chinn & Ito, 2006) index
Trade openness	Ratio of total exports and imports to GDP. A measure of the openness of the country to trade.	IMF Balance of Payments statistics
Inflation	Measure of Consumer Price Index changes in a country	IMF IFS
Gold Price	Gold price in dollars per troy ounce (2010 US dollars)	World Bank commodity price data
External debt to GDP	Ratio of the foreign currency debt holdings of the country to GDP	World Bank International Debt Statistics
Inflation volatility	Measure of annual volatility in CPI inflation	IMF IFS

Appendix Table A.2: Emerging markets and developing economies (EMDE)

Albania	Macedonia, FYR
Bangladesh	Malawi
Bolivia	Malaysia
Brazil	Mauritius
Bulgaria	Mexico
Burundi	Mongolia
Cambodia	Morocco
Cameroon	Mozambique
China, P.R.: Mainland	Nepal
Colombia	Nicaragua
Congo, Republic of	Nigeria
Costa Rica	Pakistan
Ecuador	Paraguay
Egypt	Peru
El Salvador	Philippines
Fiji	Romania
Guatemala	Russian Federation
Honduras	South Africa
India	Sri Lanka
Indonesia	Thailand
Jordan	Tunisia
Kazakhstan	Turkey
Kenya	Ukraine
Kyrgyz Republic	Vietnam
Lao People's Democratic Republic	Yemen, Republic of

Appendix table A.3: Pairwise correlations

	Gold to GDP	GLMR	GLMC	G4CBC	G4CBR	US LM Real	STR	VIX	TED spread	GDP growth	Trade openness	KA-OPEN	Pvt credit to GDP	Log GDPPC	Log IIR	Infla	Log Price	Debt to GDP	Infl Vol	USD appre
Gold to GDP	1																			
GLMR	0.1147	1																		
GLMC	0.1066	0.9962	1																	
G4CBC	0.1179	0.9454	0.9542	1																
G4CBR	0.1191	0.9374	0.9448	0.9995	1															
US LM Real	0.1335	0.8551	0.8373	0.9387	0.9442	1														
STR	-0.097	-0.7515	-0.7737	-0.8159	-0.8167	-0.7395	1													
VIX	-0.0099	-0.2031	-0.2461	-0.2779	-0.2742	-0.2755	-0.0741	1												
TED spread	-0.0578	-0.1031	-0.156	-0.3262	-0.3409	-0.5322	0.386	0.4556	1											
GDP growth	-0.0065	-0.0366	0.0119	-0.0521	-0.0608	-0.17	0.1097	-0.2255	0.0289	1										
Trade openness	0.1478	0.0425	0.0629	0.0386	0.0351	-0.0209	-0.0093	-0.0544	0.0326	0.109	1									
KAOPEN	0.1152	0.0161	0.0234	0.0004	-0.0018	-0.0466	0.0006	0.0105	0.0401	-0.0657	0.0699	1								
Pvt credit to GDP	-0.0068	0.2275	0.2282	0.2307	0.23	0.1927	-0.1769	-0.0436	-0.0327	-0.013	0.292	0.0121	1							
Log GDPPC	0.1389	0.4098	0.4225	0.3971	0.3927	0.2894	-0.3058	-0.0962	-0.0295	-0.0782	0.087	0.172	0.3594	1						
Log IIR	0.1099	0.2108	0.2214	0.1862	0.1822	0.1074	-0.1251	-0.0476	0.0319	0.0308	0.0181	0.2314	0.5815	0.6491	1					
Inflation	0.0941	-0.0797	-0.1165	-0.1039	-0.1017	-0.0872	0.1034	0.0842	0.1247	-0.0717	0.0069	-0.1291	-0.1915	-0.0917	-0.2001	1				
Log Price	0.1266	0.9663	0.9594	0.9138	0.9062	0.8006	-0.7526	-0.1706	-0.1585	0.0052	0.0617	0.02	0.2179	0.422	0.2258	-0.1048	1			
Debt to GDP	0.1053	-0.2261	-0.2526	-0.1949	-0.1884	-0.0555	0.1352	0.0286	-0.0606	-0.091	0.2242	0.0545	-0.1915	-0.3208	-0.4058	0.0707	-0.2449	1		
Inflation Vol	-0.0119	0.0437	0.0325	0.0488	0.0493	0.0609	-0.0201	-0.0283	0.0042	-0.0431	0.0229	-0.0352	-0.1332	-0.1242	-0.1221	0.1007	0.0118	0.1487	1	
USD appreciation	0.0412	0.2134	0.2302	0.4051	0.4216	0.627	-0.242	0.0327	-0.1861	-0.285	-0.0566	-0.0437	0.0924	0.059	-0.0081	-0.0063	0.1193	0.0711	0.0407	1

Appendix figure A.1: EMDE Gold holdings since 2000

The right axis indicates the EMDE central bank gold holdings in million troy ounces. Since the time series of gold holdings of EMDE central banks is auto correlated, an AR1 model (based on ACF plots) and a regime switching model with unobserved state variable is fitted to the time series data of gold holdings as per Hamilton (1989). Number of regimes chosen for the model is 2. A switch is seen in the year 2008. The bottom graph indicates the smoothed probabilities of the model once the unobserved state variable is estimated.
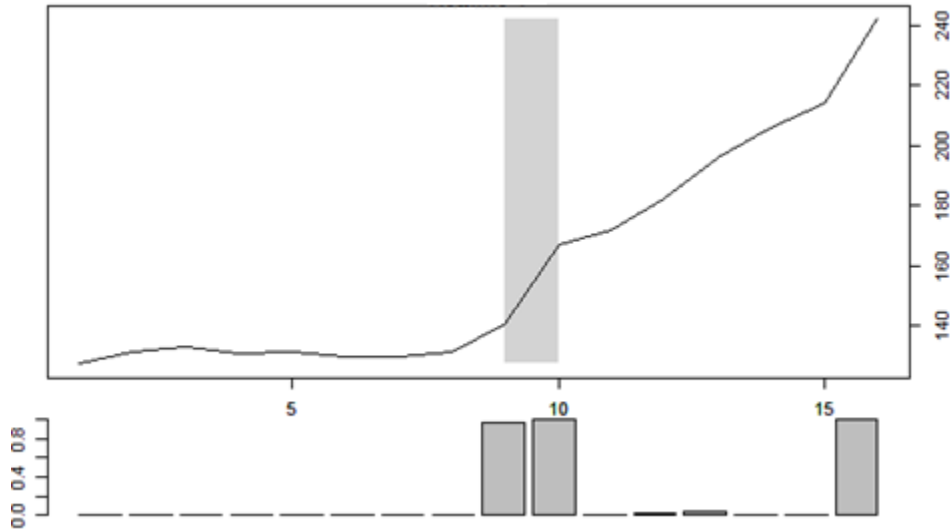
Appendix figure A.2: G4 central bank assets (trillion 2010 USD) since 2000

The right axis indicates the G4 central bank assets since 2000. Since the time series is auto correlated, an AR1 model (based on ACF plots) and a regime switching model with unobserved state variable is fitted to the time series data as per Hamilton (1989). Number of regimes chosen for the model is 2. A switch is seen in the year 2008 and 2012. The bottom graph indicates the smoothed probabilities of the model once the unobserved state variable is estimated.