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Determinants of Gold Demand in Reserve Bank of India's foreign exchange reserve portfolio.

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Abstract

Although a sizeable body of literature has studied the safe haven, inflation- and US dollar-hedge, flight-to-quality properties of gold using high-frequency gold price data, very few studies have examined the determinants of official gold holdings by central banks. This bulletin examines this for the Reserve Bank of India by using monthly data from 1995 to 2016. Employing both frequentist instrumental variable and Bayesian model averaging techniques, I find gold's US dollar and inflation-hedge properties as well as higher exchange rate risk to significantly increase RBI's gold holdings while higher equity market risks, term premium and lower market capitalization reduce such share. The results imply the rationale for holding gold by India's central bank is actually not different from private hedge fund managers or individual investors.

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1. Introduction

Although a sizeable body of literature has studied the safe haven (Baur and Lucey 2010; Baur and McDermott 2010; Ciner et al., 2013), inflation-hedge (Batten et al., 2014; McCown and Zimmerman, 2006) and US dollar-hedge properties of gold (Capie et al., 2005, Joy, 2011) using high-frequency gold price data, very few studies have examined the determinants of official gold holdings by central banks. This bulletin examines this issue for the Reserve Bank of India (henceforth RBI), the central bank of one of the largest emerging economies, and the nation that is the largest consumer of gold in the private market. Pointedly, it allows us to test some of the properties of gold that applies for private agents but also for policymaking institutions. Furthermore, it gives us deeper insights into RBI's foreign exchange reserve management strategy. Using monthly data from 1995 to 2016, and employing both frequentist and Bayesian estimation techniques, this note examines the relative importance of India's macroeconomic, financial markets and external factors in influencing RBI's gold holdings.

Central banks across the world hold foreign exchange reserves for a variety of reasons. Most of these reasons can be captured under the umbrella of "self-insurance" against financial shocks and sudden stops in the access to international capital markets, and enhancing the credibility of monetary policy. The overarching goal of securing monetary and financial stability deeply influences their reserve management decisions, which remain subordinate to it (Pilham and Hoorn, 2010). As such, reserves have traditionally been held in liquid, short-duration government bills and bonds, denominated in a handful of reserve currencies, predominantly the U.S. dollar and euro (and earlier in its main legacy currencies). International reserves are most commonly financed by domestic currency liabilities. Interest rates on such liabilities tend to be higher than that earned on the central bank's foreign currency assets. Consequently, central banks often incur a running loss from carrying low-yielding foreign exchange reserves on their balance sheets (Ramaswamy, 2008; Kaurnagaran, 2013). As a result, over the last two decades central banks have broadened the range of assets in their reserves portfolio. This diversification was driven partly, in an attempt to reduce the net financial costs of holding larger reserves, and partly to improve their reserve management practices and governance frameworks. These include US Treasury securities, agency securities, certificate of deposits, commercial paper, sovereign debt, SDRs, sovereign wealth funds and gold. This might not only improve returns but could also mitigate portfolio risks. Central banks also face market and exchange rate risks. In such a scenario, increasing gold reserves is an appealing option.

This is exactly what several central banks did during and the immediate aftermath of the global financial crisis (henceforth, GFC). Immediately after the GFC, sovereign debt downgrade to below investment grade reduced the pool of eligible investment for central banks, while contagion risks lowered the attractiveness of similar assets. Most central banks could not, simply diversify into equities (World Gold Council, 2010). Gold, which bears no credit risk, is a permissible reserve asset in practically every central bank in the world, became especially attractive in such an environment for many central banks including the RBI.[1]

2. Trends and Patterns in RBI's gold holdings.

[1] Of course, holding more gold in the central bank's foreign reserves portfolio is not without a cost. Instead of holding gold it can expect a higher nominal return on its reserves by investing them in money market instruments.

RBI's foreign exchange reserve portfolio comprises of foreign currency assets, gold, Special Drawing Rights (SDRs) and reserve tranches. Figure 1 shows the average decomposition of RBI's foreign reserves into its four constituent categories. Foreign currency assets dominate RBI's international reserve portfolio with the average share of gold at 6% over the period of study. Figures 2 and 3 show in more details the evolution of RBI's official gold holdings.

Figure 1: RBI's reserve portfolio decomposition

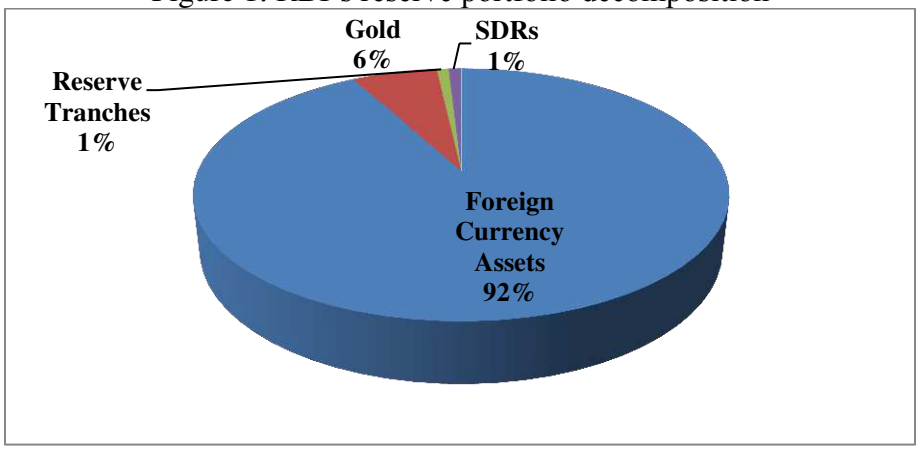


Figure 2: RBI's gold holdings

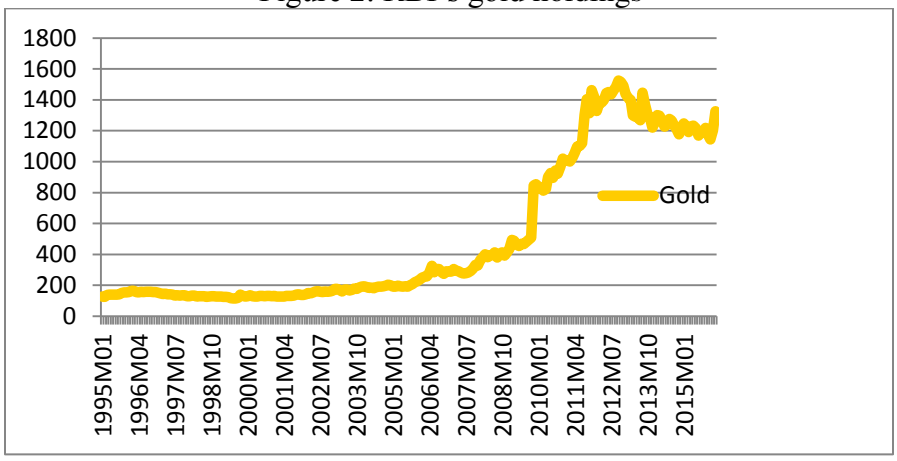
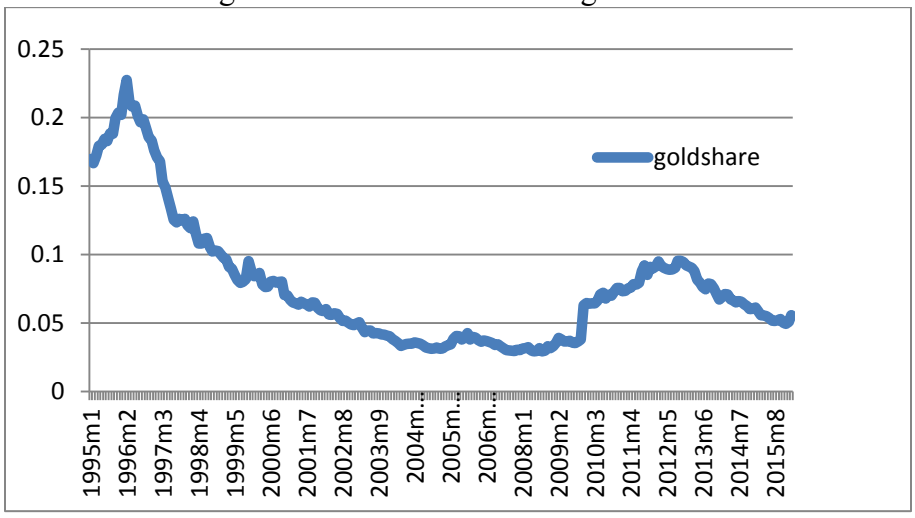


Figure 3: Gold's share in foreign reserves



RBI's gold holdings (Figure 2) show a steep increase during the period surrounding the GFC (2005-2012). Figure 3 shows the time series of gold's share in RBI's overall foreign reserves portfolio. After a steep rise from 1995 to 1997 reaching the highest value of 20%, there is a decline in gold's share that continues till the onset of the GFC. From 2009-2013 there is an increase in this share reaching the highest of around 10%.

3. Data and estimation model.

The hypothesis tested here is, do the underlying properties of gold, like dollar- and inflation-hedge, flight to quality, etc. that hold for private economic agents, and documented in the extant literature, apply for central banks, in this case the Reserve Bank of India. Moreover, I also examine the impact of India's macro-financial fundamentals on RBI's gold demand.

To this end, RBI's demand for gold is modelled from the literature on demand for physical gold by private agents (Starr and Tran, 2008) and the literature on the different properties of gold (see for example, Capie et al., 2005; Joy, 2011; Baur and Lucey 2010; Ciner et al., 2013; Batten et al., 2014). The determinants of RBI's gold holdings are estimated using the following model:

$$y_t = \alpha + \beta_i' x_t + \epsilon_t \quad (1)$$

where y_t is the ratio of gold to total foreign exchange reserves in month t. x_t is a vector of explanatory variables that include the logarithmic value of the rupee per unit of the US dollar (E), foreign exchange rate risk, log of short-term money market rates (r), changes in gold prices in the Mumbai market, real GDP growth, log of inflation rate, India's stock market capitalization-to-GDP, price-to-earnings ratio volatility in the stock market, term premium and inflation volatility, respectively.[2] Exchange rate risk is measured by the 3-month forward premium and term premium is defined as the difference between 10-year and 3-month government Treasury-bills.

The depreciation of the US dollar (appreciation of the Indian rupee here) reduces gold's price outside of India stimulating demand for it. Moreover, the depreciation of the dollar increases the cost of extracting gold overseas and often the price of other commodities used in the extraction process, putting a higher floor underneath the gold price. Thus, as the nominal value of the rupee per unit of US dollar rises i.e. the domestic currency depreciates we expect less gold holdings in the central bank's foreign exchange reserves portfolio. Apriori $\beta_1 < 0$. The forward premium captures currency risks. In world markets, gold is priced in dollars. If the dollar loses value, the nominal (dollar) price of gold will rise, thus preserving the real value of gold. In this way, gold acts as a hedge against exchange-rate risk. An increase in such risks is expected to increase the share of RBI's gold holdings. Hence, $\beta_2 > 0$. A rise in interest rates would increase the opportunity cost of holding gold that may induce RBI to decrease their gold holdings. So, it is hypothesized that $\beta_3 < 0$. Rise in the domestic price of gold is expected to reduce its demand, so $\beta_4 < 0$. Total demand for gold typically has three components: jewelry, industrial and dental, and investment demand. While jewellery, industrial and dental demand tend to be procyclical being largely determined by consumer spending power, the demand for gold from investors is counter-

[2] All volatilities are measured using 5-month moving standard deviations. GDP data are available in quarterly frequency only and are converted into monthly frequency using a cubic spline interpolation.

cyclical Demand by central banks would fall under the last category. As India's economic growth rate falls, the share of gold in RBI's foreign exchange reserve portfolio is expected to rise. I expect $\beta_5 < 0$. Gold rises in value faster when inflation gathers momentum, unlike bonds that tend to move inversely. This ability of gold to hold its real value makes it an excellent inflation hedge for individual investors as well as for central banks. Thus, a priori I expect $\beta_6 > 0$. Gold also exhibits flight-to-quality tendencies. It has a history of safe-haven inflows during times of financial distress. This stems from its lack of credit risk, but underlying all these reasons is that gold cannot be produced by the authorities that produce currencies. This implies central banks who can increase the supply of money that are often put in place to remedy financial crises, for example, through measures like quantitative easing, which can lead to inflation and erode the value of fiat currencies, cannot by similar means debase the value of gold. Thus, as the stock market capitalization-to-GDP ratio falls or the price-to-earnings volatility rises, RBI would hold more gold in the foreign exchange reserve portfolio. Hence, $\beta_7 < 0$, $\beta_8 > 0$. A rise in the term premium captures higher risks in government securities market. So, $\beta_9 > 0$. Similarly higher inflation volatility signifies higher macroeconomic instability. In such an unstable macroeconomic environment, RBI is more likely to increase their gold holdings. Thus, I expect $\beta_{10} > 0$.

Several variables used in this study like market capitalization, forward premium, money market interest rate, both the 3-month and the 10-year Treasury bond yields are available only from 1995 onwards. Hence, the data spans from January 1995 to February 2016. Table 1 shows the summary statistics of all variables sourced from RBI's database on the Indian economy. Short-term interest rates show the highest volatility followed by the 3-month forward exchange rate premium.

Table 1: Summary Statistics

	Mean	Std. Dev.	Min	Max	N
Gold share	0.077	0.047	0.029	0.227	254
Log(E)	3.824	0.168	3.446	4.202	252
Forward premium	5.272	3.513	-1.326	27.060	252
Inflation volatility	0.085	0.040	0.012	0.311	252
Log(Interest rate)	9.273	6.532	0.543	29.830	253
ΔLog(Gold price)	0.006	0.035	-0.108	0.134	252
ΔReal GDP	0.008	0.050	-0.077	0.206	231
Log(Inflation)	0.391	0.540	-2.197	1.718	243
Capitalization-to-GDP	2.545	3.079	0.243	33.714	232
Term premium	1.642	1.714	-3.478	9.176	228
Price-to-earnings ratio volatility	0.062	0.031	0.015	0.153	253

Table 2 exhibits the unit roots tests using both the augmented Dickey-Fuller and Phillips-Perron tests. Relevant variables are first-differenced to induce stationarity. Table 3 shows the correlation matrix. The share of gold exhibits the highest degree of correlation with the forward premium, and then with the term premium in the government securities market.

Table 2: Unit root tests

Variables	ADF stat.	1% level	5% level	10% level	P-P stat.	1% level	5% level	10% level
Gold share	-4.141***	-3.995	-3.428	-3.137	-4.333***	-3.995	-3.428	-3.137
Log(Gold price)	-2.494	-3.995	-3.428	-3.137	-2.485	-3.995	-3.428	-3.137
log(CPI)	-0.481	-3.996	-3.428	-3.138	-1.146	-3.995	-3.428	-3.137
Log(E)	-4.644***	-3.995	-3.428	-3.137	-4.767***	-3.995	-3.428	-3.137
Log(Real GDP)	-1.188	-4.001	-3.430	-3.139	-2.182	-3.998	-3.429	-3.138
Forward premium	-4.014***	-3.995	-3.428	-3.137	-3.665**	-3.995	-3.428	-3.137
Inflation volatility	-4.382***	-3.997	-3.428	-3.137	-3.603**	-3.995	-3.428	-3.137
Term premium	-5.034***	-3.998	-3.429	-3.138	-4.761***	-3.998	-3.429	-3.138
Capitalization-to-GDP	-5.558***	-3.999	-3.430	-3.138	-8.093***	-3.998	-3.429	-3.138
Log(Interest rate)	-5.237***	-3.995	-3.428	-3.137	-9.757***	-3.995	-3.428	-3.137
Price-to-earnings ratio volatility	-3.755**	-3.995	-3.428	-3.137	-5.998***	-3.995	-3.428	-3.137

*, **,*** indicates rejection of the null-hypothesis of unit roots at the 10%, 5%, 1% level, respectively.

Table 3: Correlation matrix

	Gold share	Log(E)	Forward premium	Inflation volatility	Log(r)	ΔGold price	ΔReal GDP	Inflation	Capitalization-to-GDP	Term premium	Price-to-earnings ratio volatility
Gold share	1										
Log(E)	-0.241	1									
Forward premium	0.597	0.347	1								
Inflation volatility	0.206	-0.122	-0.043	1							
Log(r)	0.059	0.037	0.307	-0.036	1						
ΔGold price	-0.101	-0.040	-0.174	0.046	-0.119	1					
ΔReal GDP	-0.058	0.096	-0.016	-0.159	0.011	-0.066	1				
Inflation	0.080	0.030	0.088	-0.156	-0.073	-0.032	0.185	1			
Capitalization-to-GDP	-0.145	0.220	0.059	-0.113	-0.030	0.029	0.345	-0.034	1		
Term premium	0.469	-0.642	-0.126	0.163	-0.307	-0.062	0.021	0.064	-0.187	1	
Price-to-earnings ratio volatility	0.044	-0.451	-0.240	0.002	0.130	-0.002	0.014	0.018	-0.153	0.362	1

4. Results.

4.1 Instrumental variable analysis.

I account for potential endogeneity between the regressors by using instrumental variable-GMM regressions to obtain efficient and consistent estimators. Each explanatory variable is first tested for endogeneity follow Baum et al. (2007). In concrete terms, I use a modified version of the Durbin-Wu-Hausmann test that determines which variables have to be treated as endogenous and then their lagged values are used as instruments using GMM-style instrumentation. Columns 1-4 of Table 4 present the results. I reject both the Kleibergen-Paap rank LM-statistic for under identified instruments and the Cragg-Donald Wald F statistic for weakly identified instrument. I fail to reject the Hansen J statistic for over identification, all confirming the validity of the instruments.

A 1% appreciation of the US dollar with respect to the rupee decreases RBI's gold holdings by 0.13%, supporting the US dollar-hedge properties of gold. Likewise, a rise in nominal interest rates reduce RBI's share of gold, reflecting the opportunity cost of holding gold reserves. Both forward premium and inflation volatility significantly increase gold's share implying both foreign exchange market risks and overall unstable macroeconomic environment incentivizes RBI to increase their gold holdings. Changes in domestic gold prices and inflation are statistically insignificant. Real GDP growth is positively significant in specification 2, suggesting a 'wealth effect' wherein strong economic growth boosts official gold reserves. Equity market risks, capture by the price-to-earnings volatility also increases RBI's gold demand. Similarly, a decline in stock market capitalization-to-GDP increases gold's share validating the flight-to-quality property of gold reserves. This also indicates in emerging markets like India where financial markets are in the process of development, a downturn in stock markets reduces confidence in financial markets, causing the RBI to hold more gold as a precautionary motive. Finally, an increase in term premium significantly raises gold' share indicating a rise in bond market risks causes RBI to take a conservative position by shoring up its gold holdings.

4.2 Bayesian analysis.

For robustness evaluations, I next use Bayesian model averaging (BMA) that takes into account model uncertainty by going through all the combinations of models that can arise within a given set of variables. The BMA approach expresses uncertainty about unknown parameters using probabilities, including the outcome of interest, gold's share here. BMA is relevant in because it allows considering two levels of uncertainty: the uncertainty associated with the parameters conditional on a given model and the uncertainty in the specification of the empirical model. BMA can especially yield estimations that are more robust when the small size is small, as is the case here.

From eq. (1), x_γ denotes some subset of all available relevant explanatory variables x. k potential explanatory variables yield 2^k potential models. Subscript γ is used to refer to one specific model out of these 2^k models. The information from the models is then averaged using the posterior model probabilities that are implied by Bayes' theorem:

$$p(M\gamma/y,x) \propto p(y/M\gamma,x)p(M\gamma) \quad (2)$$

where $p(M\gamma/y,x)$ is the posterior model probability, which is proportional to the marginal likelihood of the model $p(y/M\gamma,x)$ times the prior probability of the model $p(M\gamma)$. I can then obtain the weighted posterior distribution for any statistics θ:

$$p(\theta/y,x) = \sum_{\gamma=1}^{2^k} \mathrm{p}(\theta/M_\gamma \mathrm{y},\mathrm{x}) \frac{\mathrm{p}(\mathrm{M}\gamma/\mathrm{y},\mathrm{x})\mathrm{p}(\mathrm{M}\gamma)}{\sum_{i=1}^{2k} \mathrm{p}(\mathrm{y}/\mathrm{M}\gamma,\mathrm{x})\mathrm{p}(\mathrm{Mi})} \quad (3)$$

For the parameters $\beta\gamma$, I use the Zellner's (1986) g prior $\beta\gamma/\sigma^2$, $M\gamma$, $g \sim N(0, \sigma^2 g\left(x_\gamma^{/} x_{\gamma)}\right)^{-1})$

Table 4: Regression results

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
Log(E)	**-0.129*** **	**-0.119*** **	**-0.124*** **	**-0.069*** **	**-0.114** [a]	**-0.110** [a]	**-0.113** [a]	**-0.057** [a]
	(-8.69)	(-7.62)	(-8.36)	(-2.85	[0.001]	[0.001]	[0.000]	[0.001]
Forward premium	**0.011*** **	**0.012*** **	**0.011*** **	**0.01*** **	**0.010** [a]	**0.010** [a]	**0.010** [a]	**0.009** [a]
	(10.7)	(11.39)	(10.81)	(9.64)	[0.000]	[0.000]	[0.000]	[0.000]
Inflation volatility	**0.096*** **	**0.098*** **	**0.097*** **	**0.090*** **	**0.086** [a]	**0.001** [a]	**0.083** [a]	**0.069** [a]
	(3.81)	(3.71)	(3.78)	(4.17)	[0.000]	[0.000]	[0.000]	[0.000]
Log(Interest rate)	**-0.418*** **	**-0.471*** **	**-0.424*** **	**-0.237*** **	-0.152	-0.157	-0.158	**-0.031** [a]
	(-2.95)	(-3.22)	(-3.05)	(-1.94)	[0.004]	[0.007]	[0.003]	[0.002]
ΔLog(Gold price)	-0.016	-0.016	-0.011	0.019	**-0.003** [a]	-0.003	0.004	0.030
	(-0.37)	(-0.37)	(-0.25)	(0.49)	[0.002]	[0.006]	[0.005]	[0.004]
ΔLog(Real GDP)	0.030	0.028	**0.054***	0.023	0.015	0.018	**0.039** [a]	0.006
	(1.2)	(1.12)	(1.95)	(0.91)	[0.002]	[0.003]	[0.001]	[0.003]
Log(Inflation)	0.000	-0.001	-0.001	0.000	**0.002** [a]	**0.002** [a]	**0.001** [a]	**0.002** [a]
	(-0.03)	(-0.17)	(-0.22)	(-0.09)	[0.000]	[0.000]	[0.000]	[0.000]
Capitalization-to-GDP			**-0.001*** **	**-0.001** **			**-0.001** [a]	**-0.001** [a]
			(-2.96)	(-2.25)			[0.000]	[0.000]
Term premium				**0.006*** **				**0.007** [a]
				(2.75)				[0.000]
P/E ratio volatility		**0.131***				**0.067** [a]		
		(1.68)				[0.001]		
constant	**0.533*** **	**0.489*** **	**0.519*** **	**0.289*** **	0.462	**0.441** [a]	**0.460**[a]	**0.231**[a]
	(9.64)	(8.42)	(9.41)	(3.03)	[0.003]	[0.002]	[0.001]	[0.002]
N	222	222	222	216	222	222	222	217
F	20.58	18.77	18.96	40.79				
R2	0.566	0.546	0.573	0.674				
Kleibergen-Paap rk LM-stat	13.91***	13.742***	13.644***	10.314***				
Cragg-Donald Wald F-stat	14.41***	12.627***	14.3***	7.692***				
Hansen J-stat	0	0	0	0				
Acceptance rate					0.342	0.32	0.327	0.294
Efficiency rate					0.193	0.199	0.203	0.189

Terms in brackets denote z-stats based on robust standard errors. *, **,*** indicates significance at the 10%, 5%, 1% level.
Terms in square brackets denote Monte Carlo standard errors [MCSEs]. [a] denote significant post-estimation means based on low values of MCSEs.

Columns 5-8 of Table 4 presents the posterior mean estimates of the BMA analysis, along with their Monte Carlo standard errors (MCSEs) using the Markov chain Monte-Carlo model composition (MC^3) method. This is implemented by using a random-walk Metropolis-

Hastings algorithm with 12,500 iterations.[3] The posterior means are comparable to the corresponding coefficient estimates of the frequentist techniques. Results are very similar to the frequentist instrumental variable approach. An appreciation of the US dollar vis-à-vis the rupee reduces RBI's gold share. Both the forward premium and inflation volatility, capturing foreign exchange market risk as well as macroeconomic instability, increases gold demand. The results for short-term interest rates are negatively significant only in eq. (8). A decline in stock market capitalization-to-GDP reduces gold's share while rise in both price-to-earnings volatility and term premium increases it. Additionally, improving over the instrumental variable estimations, rise in gold prices significantly reduces gold's share (eq. 5) while increase in India' inflation rate increases it (in all four specifications), both consistent with theoretical priors. The latter also reveals inflation hedging properties of RBI's gold reserves.

5. Conclusion

I find the reasons for gold holdings in RBI's foreign reserves are actually not different from private agents. Precisely, the US dollar and inflation hedge properties of gold as well as higher exchange rate risks have decisively influenced RBI's gold management. The same applies for risks arising from India's domestic equity and bonds markets.

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[3] The BMA results are robust to sensitivity analysis performed to evaluate the influence of different competing priors.

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