

# Optimal gold allocation for emerging-market central banks

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The following is a reprint of Chapter 5 of the RBS Reserve Management Trends 2012, published by Central Banking Publications and reprinted courtesy of the World Gold Council.

Now in its eighth year, the only annual survey of central bank reserve managers provides candid insights into the thinking of official sector portfolio managers. RBS Reserve Management Trends 2012 features an exclusive report of a survey more than 50 central banks, responsible for more than \$5 trillion in reserve assets, on their reaction to the global financial crisis and how they view the key questions facing financial markets and the international monetary system.

The book, published on April 17 2012, features chapters from reserve managers, central bankers and market observers on the important themes of diversification, asset allocation, gold holdings, Chang Mai and outsourcing. In an exclusive interview, the head of reserve management at the Bank of Korea explains the central bank's strategy in the crisis and discusses changes to how the reserve management function is organised and plans for adding the renminbi to its reserve portfolio.

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# 5

## Optimal gold allocation for emerging-market central banks

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by Ashish Bhatia

In 2010, central banks turned net buyers of gold for the first time in two decades. In 2011 that trend continued with central banks purchasing more than 400 tonnes of gold. Part of this was driven by the decreasing attractiveness of other reserve assets like sovereign bonds, which have been severely undermined by the sovereign debt crises of 2011–12. Gold’s lack of credit risk, market depth, and the fact that it is almost universally permissible in the investment guidelines of the world’s central banks has made it an attractive alternative.<sup>1</sup> Beyond the prevailing economic environment, another factor driving demand for gold in the official sector has been that gold has been relatively under owned by emerging-market central banks. While advanced economies held, as end-2011, on average 22% of their reserves in gold, emerging-market central banks held on average less than 4%.<sup>2</sup> Given this relative under-allocation to gold, many reserve managers in these markets have been wondering how much gold is optimal. The aim of this chapter is to help address this question by building on past research and examining the question from a uniquely local, domestic currency perspective. This study examined the performance of a typical central bank reserve portfolio when denominated in nine emerging market currencies and found that the median range of optimal allocations to gold increased to 8.4% to 10.0% (from 4.6%–7.0% in dollar terms). The results point to an often overlooked stability of gold’s volatility in a range of currencies, which when compared to the instability of the volatilities of other reserves assets (dollar, euro, yen, and sterling government bonds) – supports higher optimal allocations to gold for most emerging market central banks.

This chapter is divided into five sections. The following examines the question of the choice of numéraire and the impact this can have on reserve holdings. Section two describes the methodology used to calculate gold allocation. Sections three and four describe the results of the study for dollar and domestic currencies respectively. A final section concludes.

## Why consider a non-US dollar numéraire?

Past optimal allocation studies have found a clear role for gold in central bank reserve portfolios, although until now, such studies have largely been confined to dollar-based portfolios.<sup>3</sup> The result of the dollar analysis in Case 1 of this study finds an optimal allocation to gold of between 1.5% and 16%, with a median range of between 4.6% and 7.0% depending on risk tolerance. Extending this analysis by changing the numéraire (for example, to the Mexican peso) removes the bias of an analysis conducted in dollar terms and makes the results valuable from a domestic perspective. Utilizing a domestic numéraire will also help reserve managers understand how a change in the relationship between the domestic currency and the dollar, such as the introduction of a more flexible exchange rate, would impact optimal gold allocations.

A reserve manager would want to extend a dollar-based optimisation to a domestic currency (non-dollar) perspective for one of three reasons: (1) to reduce the bias of their analysis conducted in dollars, (2) to assess efficiency/robustness of the analysis in the domestic currency, and (3) to consider how the changing nature of their domestic currency's relationship to the dollar may impact the results.

On the first reason, increasingly, academics and practitioners realise the bias that the selection of a numéraire has on the results of a portfolio optimization.<sup>4</sup> The Reserve Bank of Australia describes the issue of numéraire selection and the resulting bias in its discussion of its reserves management process. The Reserve Bank states:

Using a non-domestic currency (such as the US dollar or euro) as the numéraire avoids the moral hazard problem and may be attractive if it is the currency of choice for intervening in foreign currency markets. The downside to such a numéraire is that it is likely to distort portfolio management decisions. For example, if the US dollar were used as the numéraire and it is one of the investment currencies it is quite likely that the 'optimal' currency composition of the portfolio would only contain US dollar assets. This is because a portfolio that only consists of assets expressed in the numéraire would involve no currency risk and would therefore tend to have the lowest risk profile.<sup>5</sup>

Consistent with the Reserve Bank's primary concern that the lowest risk profile portfolio will include almost entirely currencies of the numéraire, the lowest risk portfolio in the dollar analysis conducted in this study allocated 92.2% of all reserves to the dollar assets (US Treasuries and agency securities). Thus, if the goal of any given central bank is to minimise risks in *US dollars terms*, holding only US dollars will help to at least eliminate currency risk. However, allocation to only US dollars or even a majority

allocation to dollars significantly limits the diversity of a reserve manager's assets – which brings a new set of risks. Given that dollar-based analyses will result in biased results toward dollar assets, it will be valuable to an increasing number of reserve managers to consider their official reserves from a domestic currency perspective, in part to ensure proper diversification.<sup>6</sup>

Secondly, many reserve managers need to be mindful of their portfolio performance from a domestic currency perspective. This may be due to concern or interest from government officials and the public in maximising profits or at least minimising losses, especially as central banks typically report foreign holdings in local currency terms. It may also stem from the central bank's need to rely on interest income or profits to sustain the central bank's operations.

The last reason that reserve managers may consider a change in the numéraire in their optimisation exercises is to consider a potential changing role of their currency vis-a-vis other reserve currencies, with particular attention paid to the dollar. Many economists and policymakers question whether the dollar's role as a, or the, primary reserve currency will last in the evolving international monetary system. The emergence of the renminbi has reignited this as a topic of increasing interest. An important likely implication of a smaller role for the dollar in global foreign exchange and in official reserves is that the dollar may become more volatile against other currencies.

A reserve manager may also be interested in this dynamic if he or she is considering adding more flexibility to their currency policy. For example, moving from a fixed exchange rate relative to the dollar to a more flexible regime will introduce greater volatility against the domestic currency and other reserve currencies. This then makes a domestic currency analysis more fruitful and possibly insightful as to where a portfolio needs to evolve. For all three of these reasons, there is a strong case to analyse optimal allocations from both a US dollar and domestic currency perspective. The following section sets out the optimisation process used in this study.

## Methodology

The inputs required for this optimisation analysis were:

- 1 Choice of assets for the investment universe;
- 2 Period of analysis of historical data for determining the return, volatility, and correlation assumptions for the selected assets and currencies; and
- 3 Methodology to find optimal portfolios

*Assets:* The assets selected for this analysis were based on the International Monetary Fund's (IMF) COFER breakdown of the top four official reserve currencies (dollar, euro, sterling and yen) which account for approximately 95% of all aggregate foreign currency reserves.<sup>7</sup> The investment universe was based on the asset indices from Barclays Capital and JP Morgan listed in Table 5.1. In all currencies, the sovereign debt index was selected; additionally, in the case of the dollar, the US Agencies index was included as reserve managers have been significantly invested in this asset class in the past. Gold returns and volatility are based on the benchmark gold price of the London pm fix rate,<sup>8</sup> published by the London Bullion Market Association (LBMA).

*Historical period:* Monthly historical data from March of 1998 to June of 2011 was used for this study.<sup>9</sup> Since this study examines the impact of various foreign currencies, it was important to start the period after the Asian financial crisis, to exclude the extremely volatile foreign exchange periods between 1997 and 1998 for most the currencies examined.<sup>10</sup> Foreign currency returns, volatilities, and correlation matrices were based on the same historical data and periods. Index returns were rebased in foreign currency terms by utilising published foreign exchange rates,<sup>11</sup> then rebased indices (eg, US Treasury Aggregate in Brazil real) were used to calculate domestic currency returns, volatilities, and correlation matrices.

*Assumptions:* While reserve assets, in particular advanced economy fixed income assets, are unlikely to repeat the impressive performance they exhibited in the past 12 and a half years, by utilising historical returns the challenges associated with forecasting returns and volatility based on any number of approaches were avoided.<sup>12</sup> Since gold was the primary focus of this analysis, a more conservative estimate for gold's return was deemed appropriate. Therefore gold's historical performance of an annual return of 13.5% for the period between 1998 and 2011 was reduced significantly to only 4%.<sup>13</sup>

**Table 5.1 Assets used in the study**

<b>Assets</b>	<b>Return (%)</b>	<b>Volatility (%)</b>
Barclays Capital US Treasury Aggregate	5.6	4.8
Barclays Capital US Agency Aggregate	5.5	3.5
JPMorgan German Bund Index (euro)	5.0	3.7
JPMorgan Japan Bond Index (yes)	2.0	2.9
JPMorgan UK Gilt Index (sterling)	5.8	5.2
Gold (London pm fix) actual results (dollar)	13.5	16.5
Gold inputs used for this study	4.0	16.5

Source: Bloomberg, Barclays Capital, JPMorgan, LBMA and author's calculations.

*Optimization method:* In order to analyse this data New Frontier Advisors (NFA) patented portfolio optimiser, which pioneered the technique of resampled efficiency optimisation, was used. The Michaud Re-sampled Efficient Frontier™ has been acknowledged by Harry Markowitz, founder of modern risk-adjusted return portfolio theory, to be more effective and robust than classical mean-variance optimisation.<sup>14</sup> In particular the re-sampled portfolio results tend to be more robust and less reliant on the accuracy of return and volatility assumptions.<sup>15</sup>

All portfolios were assumed to be long-only; additionally, a constraint, on the maximum amount of US Agencies (25%) was included in the optimiser.<sup>16</sup> The vast majority of the results in this study were significant at the 5% level, providing a confidence level of 95%. The remaining results were significant at the 90% or 75% confidence level. Table 5.2, below, illustrates the primary results and the associated confidence levels of Case 1 and Case 2.

**Table 5.2 Optimal gold allocations and confidence levels (%)**

	USD	BRL	IDR	INR	KRW	MXN	PHP	PLN	SGD	THB	Average of EM currencies
Minimum Risk	1.4	20.0	10.5	6.4	2.5*	6.4	7.1	5.4	6.4	5.3	7.8
Statistically significantly different from USD analysis	Yes	Yes	Yes	No	Yes**	Yes	No	Yes	Yes**		
Mid-Range (Median results)	4.6**	19.2	12.1	6.4	3.9**	6.7	8.0	7.4	6.0	5.8	8.4
	7.0**	19.5	14.1	7.7	5.9**	8.3	9.9	9.7	7.3	7.4	10.0

All results were significant at the 95% confidence level, except those labeled (\*90% level or\*\* 75% level). Source: author.

## Terminology used in this study

### Optimiser results

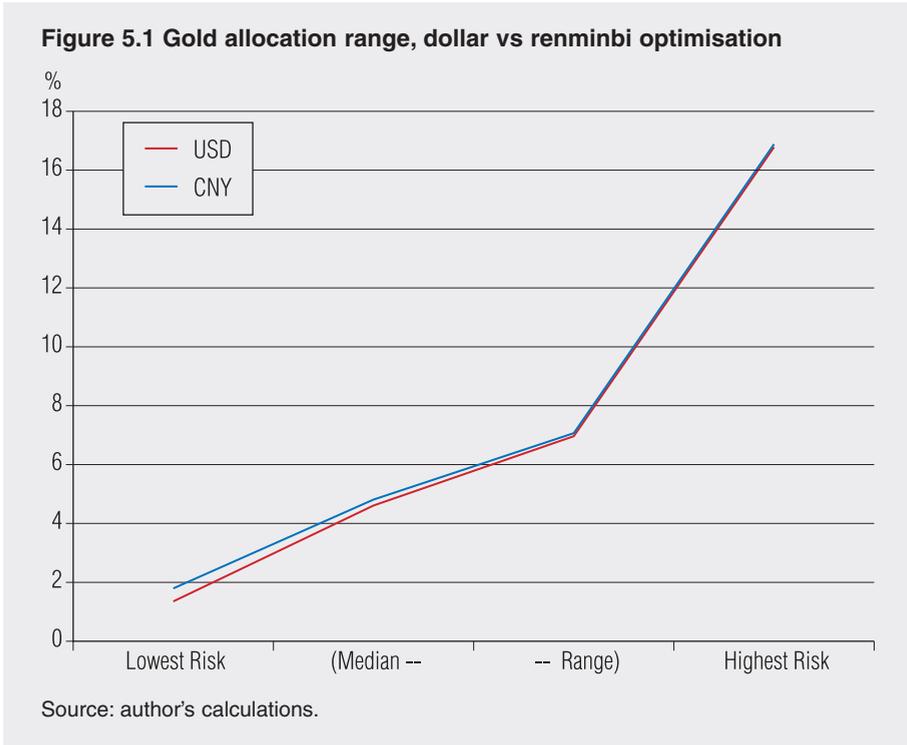
For each currency that was analysed the optimiser drew from a multi-variate normal distribution to generate 1,000 efficient frontiers which were then averaged to create the Michaud Re-sampled Efficient Frontier™. This efficient frontier is represented by 51 optimal portfolios that correspond to asset allocations that maximise return for a given level of risk. While it is customary to analyse portfolio results by comparing

returns for a given level of risk, such a comparison is not possible across multiple currencies as the level of volatility or risk for each currency can range significantly. For example the minimum risk optimal portfolio in Brazilian real terms has a volatility of 19.3% versus the minimum risk portfolio in Singapore dollars of 5.5%. Thus, in presenting and comparing results across various currencies, this study refers to three areas of the efficient frontier to approximate a consistent comparison across

### **Box 5.1 Country selection and the impact of fixed exchange rates**

Since there are 177 central banks and national central banks in the world, currencies for this analysis were selected by filtering countries by three screens.<sup>18</sup> First, only currencies of countries that held more than \$50 billion in reserves were chosen. Second, advanced economy countries were removed as this analysis was focused primarily on emerging-market central banks that have smaller allocations to gold. Finally, countries with less flexible currencies were removed. This last criterion was very important and removed several notable emerging-market currencies such as the Chinese renminbi and the Russian rouble (other currencies from Saudi Arabia, Taiwan, Hong Kong, Malaysia, Turkey and Hungary were also removed do their limited flexibility). When conducting the analysis in countries that were tied closely to the dollar to the euro, the results overwhelming were skewed to assets in US dollars or euros, respectively – which made the analysis effectively similar to running the analysis in dollar or euro terms. Therefore an important requirement for a change in numéraire analysis requires a currency that is more flexible. Figure 5.1, below, illustrates the results for China which closely match that of the analysis when conducted in dollars, making the two lines virtually indistinguishable.<sup>19</sup>

While countries with an explicit fixed rate regime were excluded, several of the currencies remaining in this study still have some level of monetary authority influence on the exchange rate. In particular it is well known that monetary authorities conduct regular volatility smoothing operations in Korea won and to some extent in other currencies in this analysis. Additionally, Poland's long-term strategic alignment toward potentially joining the euro, leads to a strong stability of Polish zloty to euros. There is a possibility that some of the smoothing activity was captured in this analysis and may for example explain the lack of statistical significance of a few of the results.<sup>20</sup> ▷



currencies: (1) the “minimum risk portfolio” which is the allocation that provides the lowest level of risk; and (2) the “median risk,” “mid-range” or “medium” risk portfolios which are the portfolios that are approximately in the middle of the efficient frontier.<sup>17</sup>

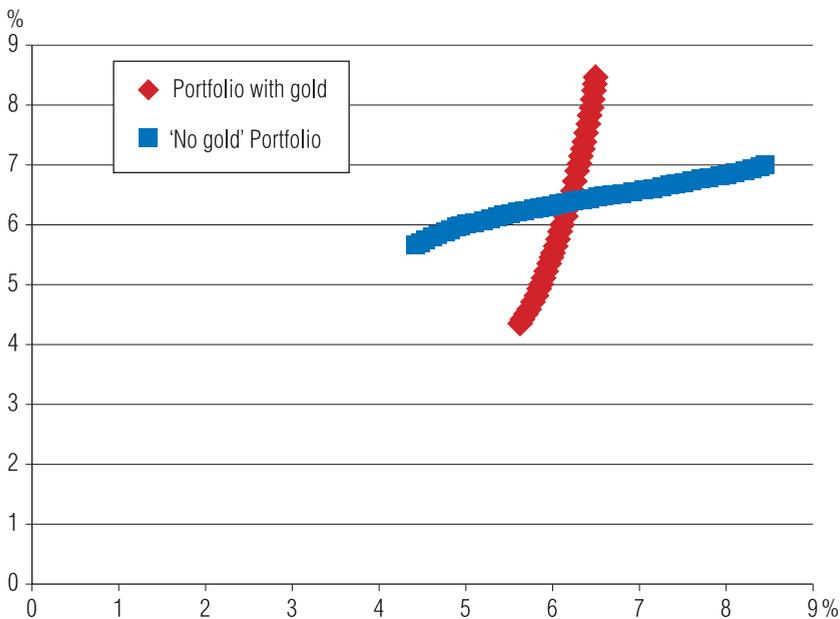
### Currencies (dollar, local, domestic)

This analysis compares the results of an optimisation analysis conducted in Case 1 based on “dollar based” assumptions (return, volatility and correlations) and those conducted in nine selected emerging-market currencies that are analysed in Case 2. The usage of the phrase “local currency” means the actual return, volatility and correlation results from the currency of the origin of the asset. For example, the local returns and volatility of German bunds would be the returns and volatility calculated in euro terms. The analysis conducted on German bunds in Case 2 examines the ‘domestic currency’ terms which involves converting the euro-denominated German bund returns into one of the selected nine emerging-market currencies (ie, German bund returns in Mexican pesos or Brazil real).

## Results from Case 1: dollar

The results of the US dollar numéraire analysis showed that gold improved risk-adjusted returns for median levels of risk and higher. The efficient frontiers of a portfolio including gold and a portfolio excluding gold are plotted in Figure 5.2 illustrating a “V” shaped set of optimal frontiers.<sup>21</sup> The NFA optimiser through its 1,000 simulations also showed that the optimal gold allocation from a dollar perspective ranged between 1.4% and 16.8% with the median range between 4.6% and 7.0% which is plotted in Figure 5.3.

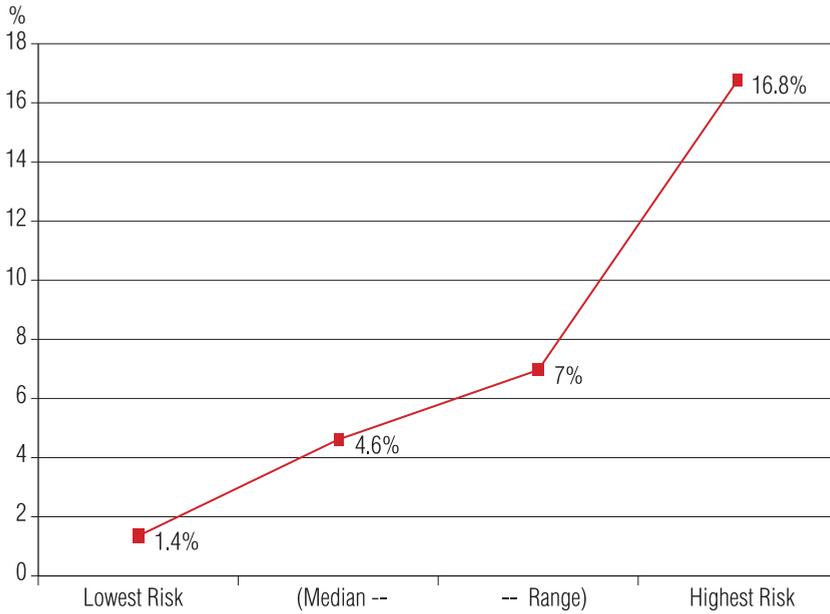
**Figure 5.2 Dollar as numéraire: efficient frontiers, portfolio growth and ‘no gold’**



Source: author's calculations.

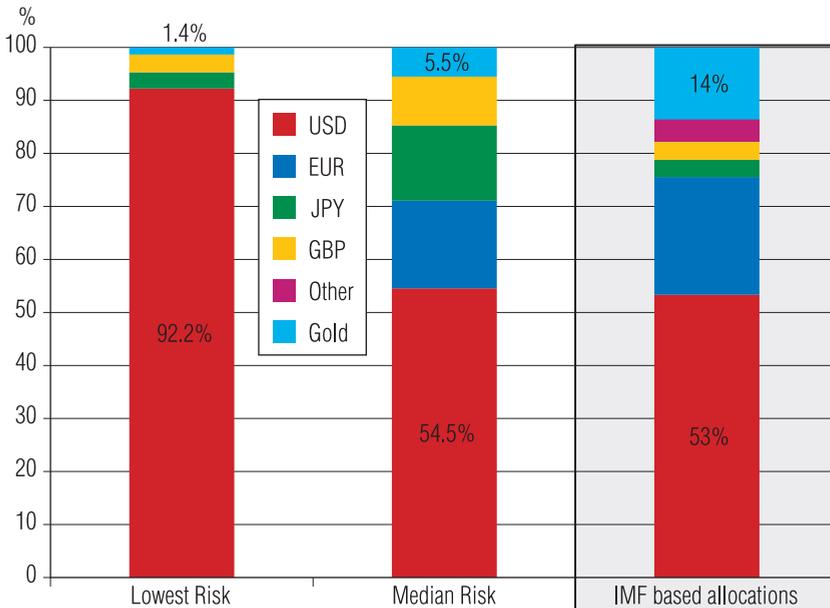
There are several observations that can be drawn from these results. First, results in the median range between 4.6% and 7% were consistent with aggregate reserve allocations based on the IMF COFER data which is qualitatively supportive of the results of this analysis. Second, despite gold's return being constrained to only 4%, which had the effect of reducing gold's information ratio to the lowest of all other reserve assets, gold's low correlation with other reserve assets resulted in the optimiser finding significant value in gold, and thus including it at a statistically significant level in the optimal re-sampled efficient frontier.<sup>22</sup> Finally, as noted earlier, the lowest risk portfolio did in fact skew allocations toward dollar assets, allocating 92.2% of the lowest risk portfolio to

**Figure 5.3 Dollar as numéraire: optimal gold allocations at various levels of risk**



Source: author's calculations.

**Figure 5.4 Dollar as numéraire: dollar bias in low risk portfolio vs median risk**



Source: IMF COFER data as of Q3 2011 and author's calculations.

US agencies and US Treasuries, due substantially to their lower domestically (dollar) based volatilities. Figure 5.4 illustrates the bias of the lowest risk portfolio against the median risk portfolio and plots in a box the aggregate allocation of global reserves which are fairly similar to the median risk portfolio.

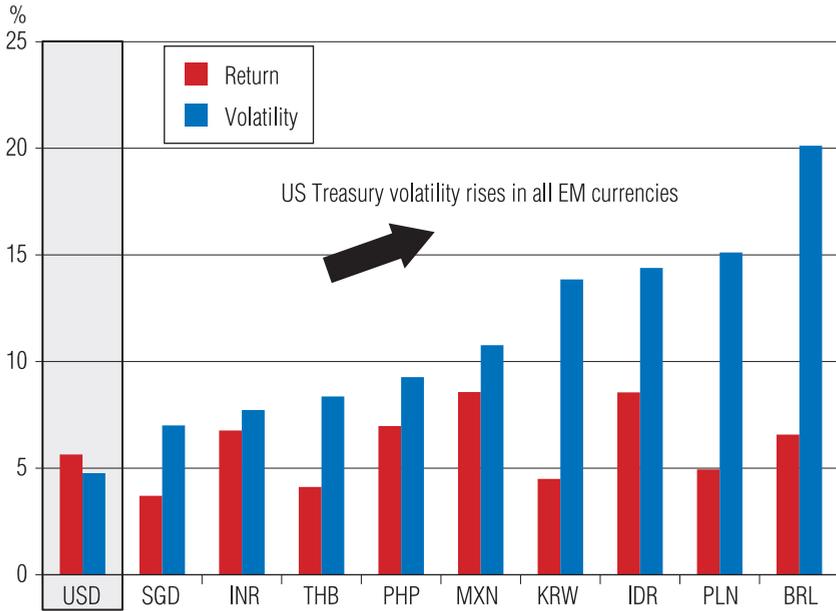
In many past studies and for many practitioners, this is potentially the extent of the quantitative analysis that is typically conducted for reserve managers that only manage their official reserves portfolios to optimise dollar-based performance. For these reserve managers, maximising the amount of dollars available and minimising risk in US dollars is the only concern.

### **Impact on inputs from changes in the numéraire**

When examining the same set of assets described in the dollar based portfolio from the perspective of an emerging-market domestic currency, the changes start with the inputs of the analysis. Including a foreign exchange overlay changes return and volatility assumptions and historical correlations. As in the previous case, the analysis relied on historically observed returns and volatility for all assets, which resulted in returns being improved or eroded by long-term return of the domestic currency pair. Clearly currencies that have depreciated against the dollar over this period may not continue in that trend, or vice versa; however for this study the relationship is assumed to be carried forward. The results show that there does not appear to be a clear relationship between an appreciating or depreciating currency and optimal gold allocations. Rather the volatility of the currency pair appears to be more meaningful.

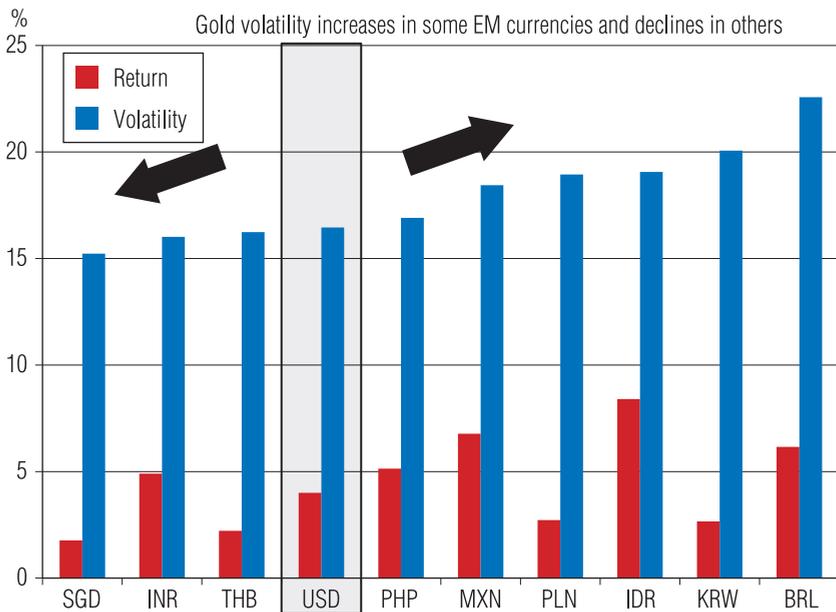
As an example, Figures 5.5–5.7 illustrate how a foreign exchange overlay impacts the inputs for gold and US Treasuries. While US Treasuries are not very volatile in US dollar terms with annualised volatility of 4.8%, US Treasury volatility from an emerging-market domestic currency perspective rises significantly in each of the selected nine currencies exhibited in Figure 5.5 (For example, US Treasury volatility rises by six percentage points in Mexican pesos terms to 10.8%). Meanwhile gold's volatility of 16.5% for this period increases in some currencies but decreases in others exhibited in Figure 5.6 (for example, gold volatility in Singapore dollars declines by 1.3 percentage points to 15.2%). The same is true for asset returns for both US Treasuries and gold. However both are more equally impacted by the foreign exchange overlay. Finally, the correlation matrix changes for these assets as now the foreign exchange overlay increases the correlation of all asset pairs as they react to the similar increase or decline in the currency pair. However, despite the foreign exchange overlay, Figure 5.6 shows that gold's correlation to other reserve assets remains almost universally the lowest, or the least correlated to the other assets with, or without, the foreign exchange overlay.

**Figure 5.5 Rebased US Treasury aggregate returns and volatilities**



Source: author's calculations.

**Figure 5.6 Rebased gold returns and volatilities**



Source: author's calculations. As noted in methodology, gold return in US dollars was reduced to 4.0%.

**Figure 5.7 Correlation matrix with US dollar vs Mexican peso as numéraire**

US dollar numeraire portfolio correlation matrix

	US Treas	US Agencies	GER Bunds	JGBs	UK Gilts	Gold
US Treas	1.000					
US Agencies	0.952	1.000				
GER Bunds	0.497	0.548	1.000			
JGBs	0.340	0.294	0.361	1.000		
UK Gilts	0.422	0.468	0.734	0.240	1.000	
Gold	0.214	0.252	0.392	0.221	0.337	1.000

Mexican peso numeraire portfolio correlation matrix

	US Treas	US Agencies	GER Bunds	JGBs	UK Gilts	Gold
US Treas	1.000					
US Agencies	0.989	1.000				
GER Bunds	0.707	0.704	1.000			
JGBs	0.748	0.743	0.630	1.000		
UK Gilts	0.732	0.735	0.830	0.600	1.000	
Gold	0.474	0.482	0.482	0.443	0.506	1.000

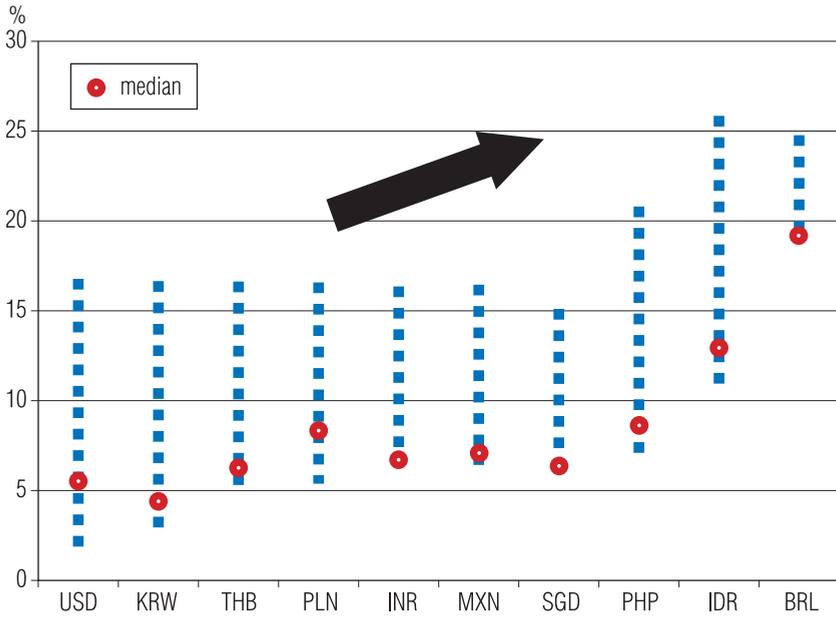
*Lower correlation values are highlighted in blue and higher correlations are in red*

Source: author's calculations.

## Results from Case 2: nine domestic currency studies

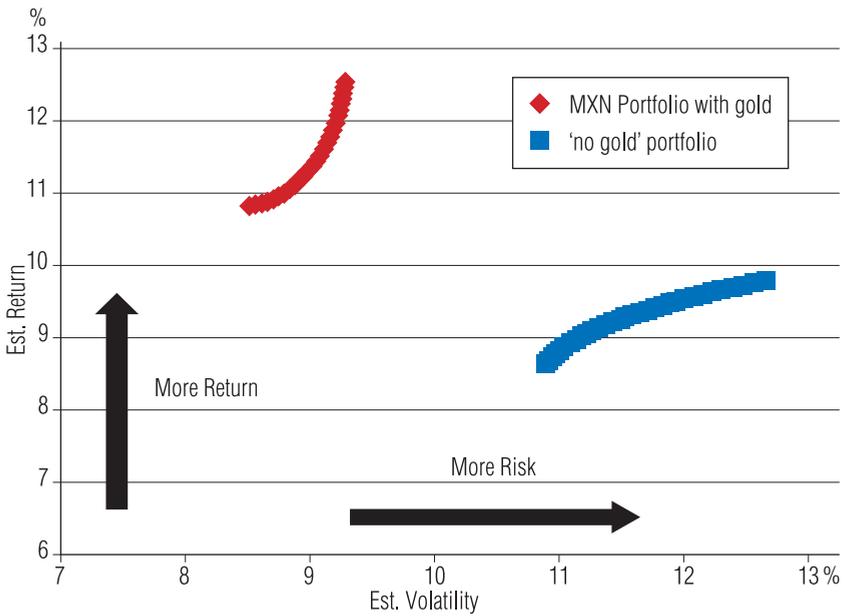
The results of nine distinct optimisation analyses in domestic emerging-market currencies show that allocations to gold are statistically significantly higher in each currency examined relative to the US dollar analysis, see Figure 5.2. Indeed, optimising a typical emerging-market central bank portfolio from a domestic currency perspective for the selected emerging-market countries revealed that the dollar-based optimisation consistently under allocated to gold when compared to the domestic currency. The optimal gold allocation ranged from 2.4% to 25.8%, with a median gold allocation of the group between 8.4 to 10%.<sup>23</sup> Figure 5.8 illustrates the range of results by currency by charting the optimal gold allocation for a minimum risk portfolio to the maximum risk portfolio, with the median optimal gold allocations highlighted by a circle.<sup>24</sup> The results show that the dollar-optimized portfolio had the lowest optimal gold allocation for the minimum risk portfolio, likely due to its dollar bias – where it allocated 92.2% of all assets to dollar assets. Finally, in all currencies examined, portfolios with gold dominated portfolios not including gold, meaning that by adding gold to these reserve portfolios, risk-adjusted returns were improved, often considerably. Figure 5.9 charts an example for the Mexican peso showing that a portfolio with gold is considerably less risky and offers greater return than a portfolio without gold.

**Figure 5.8 Optimal gold allocation range and median by currency**



Source: author's calculations.

**Figure 5.9 Mexican peso as numéraire: efficient frontiers, portfolio with gold and “no gold”**

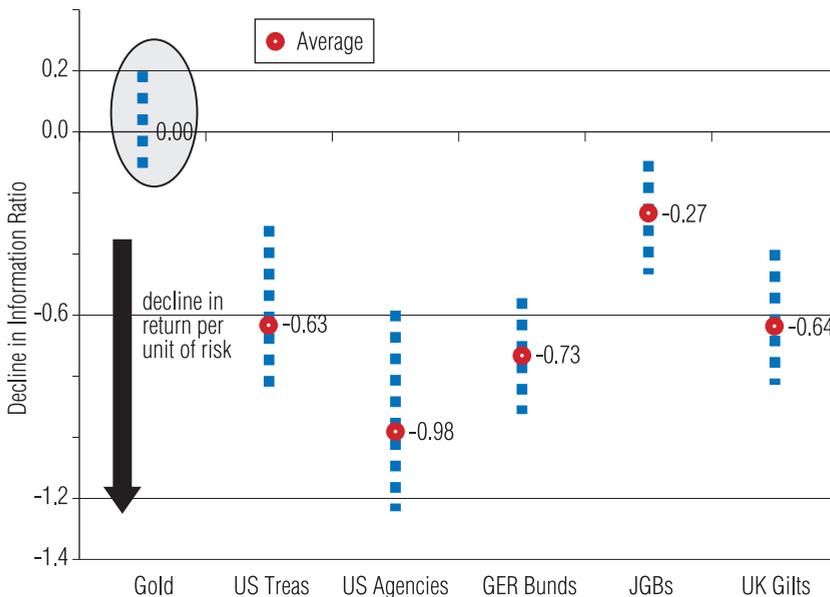


Source: author's calculations.

## The stability of gold, and why higher allocations may be optimal

Comparing the optimal allocation to gold from a dollar and domestic currency perspective – yields an intriguing quality about gold which helps to explain why from a domestic currency perspective gold allocations should be higher in all nine currencies. This result is based on gold’s behaviour as both an asset and currency, in one. In dollar terms, gold has the lowest information ratio and the highest volatility relative to all other reserve assets. However, when examined in each of these selected emerging-market currencies, while gold continued to have the lowest information ratio, its information ratio was much less impacted than other reserve assets by changes in the numéraire.

**Figure 5.10a Range of impact on the information ratio of rebasing assets into EM currencies**



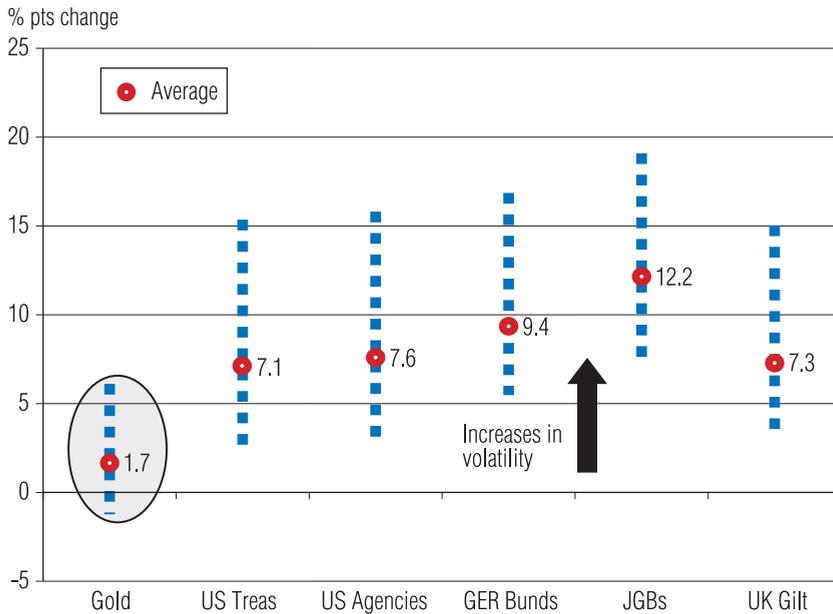
Source: author calculations.

Figure 5.10 illustrates the impact these currencies had on each reserve asset’s information ratio and in each respective currency, which shows gold as the least impacted reserve asset. In fact, the average change in gold’s information ratio when rebased in a foreign currency was zero. Meanwhile the average decline in return per unit of risk (information ratio) for US Treasuries was approximately 0.6 and almost one full point for US agencies. Thus, despite having the lowest information ratio, gold’s information ratio is more stable

across all currencies. Given that the information ratio is computed as the return of an asset divided by its volatility, the finding suggests that the stability of gold's volatility from currency to currency as the primary contributing factor to this result.

Gold's volatility is significantly more stable than the volatility of other reserve assets in this range of currencies. Figure 5.10b charts the range of change in volatility of gold across the nine emerging-market currencies and illustrates that gold's volatility on average increased by only 1.7 percentage points. Meanwhile for all sovereign debt instruments volatilities consistently rose by more than 7.0%. Thus while sovereign debt is often considered a low risk, low volatility asset, when considered outside of a US dollar perspective, it is much more volatile.

**Figure 5.10b Range of impact on volatility of rebasing assets into EM currencies**

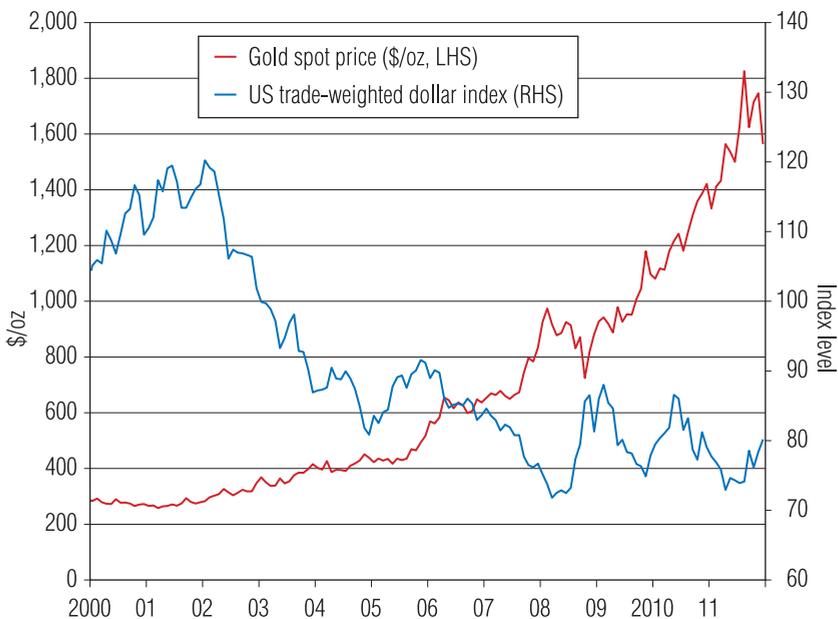


Source: author's calculations.

Gold's negative correlation with the US dollar underpins the stability of gold volatility. Over a long horizon, gold has been negatively correlated to the dollar, in part as gold's price is typically referenced in dollar terms. The logic behind this phenomenon is that when, for example, the Mexican peso appreciates against a weakening dollar, gold is likely to also appreciate given its negative relationship with the dollar, which means that the Mexican peso

and gold will tend to move in the same direction – thus reducing the amount of volatility of the MXNXAU<sup>25</sup> pair. Gold’s negative correlation with the dollar is in fact one of gold’s qualities that many central bank reserve managers consider particularly attractive as a reserve asset: it can serve as a hedge against dollar assets. Figure 5.10c illustrates gold’s negative correlation with the US dollar traded weighted index just since 2000 which on average had a correlation coefficient of -0.44.<sup>26</sup> This fairly significant negative correlation with the US dollar not only eases gold’s volatility on other currencies, it also hedges against a long-term decline in the dollar.

**Figure 5.10c Gold versus trade-weighted dollar index**



Source: author’s calculations.

## Conclusion

The results of this analysis conducted in nine emerging-market currencies showed that the optimal allocation to gold is consistently higher than when considered from a dollar perspective, with a median resulting optimal allocation to gold of between 8.4% and 10% (compared with 4.7% to 7% in dollar terms). Additionally, including gold in the investment universe improved risk-adjusted returns for all nine emerging-market currency optimisations – shifting the efficient frontier north and west. The analysis

points to an underlying quality of gold – that gold’s volatility is very stable across emerging-market currencies. Furthermore, it is exceptionally stable when compared to the relative instability of other typical reserve assets like sovereign bonds. In reaching this conclusion, this study reaffirmed the fact that optimisation analysis conducted in dollar terms resulted in a dollar biased portfolio – whereby the lower risk portfolios in the resulting “optimal” efficient frontier will be significantly weighted toward dollar assets.

While strategic asset allocation decisions for reserve managers involve many variables that often cannot be modelled, modern portfolio theory can support reserve managers’ understanding of trade-offs and the portfolio behaviour of assets. When comparing gold to other reserve assets, reserve managers will already be aware of gold’s liquidity and lack of credit risk. However when comparing gold to other reserve assets, many may only conduct a comparison in dollar terms, which this chapter has shown is not a complete comparison. As reserve managers prepare for what many are considering a new era in the international monetary system, defined by the diminishing role of the dollar, reserve managers can benefit from considering investment assets from their own currency perspective. As part of this new era, many countries may move from a fixed or less flexible exchange rate regime to a more flexible one or simply a different peg. In either case, increased volatility will naturally ensue in their currency’s movement against other global currencies – making a single lens of observation through the dollar obsolete. For all of these future unknowns, understanding gold’s behaviour as a truly global asset will support effective reserve management decisions.

## Notes

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1. For a comprehensive perspective on the size and depth of the gold market see “Liquidity in the Global Gold Market”, World Gold Council, April 2011.
2. IMF International Financial Statistics.
3. Several past studies have found some role for gold in a reserve asset portfolio with differing degrees of allocation. See: Scacciavillani and Saidi, “The Case for Gold as a Reserve Asset in the GCC (Dubai: Dubai International Financial Centre, 2010); Natalie Dempster, “The Importance of Gold as a Reserve Asset”, World Gold Council, 2010; Carlos León and Daniel Vela, “Strategic asset allocation: non-loss constraints and long-term dependence,” in *RBS Reserve Management Trends 2011*, ed. R. Pringle and N. Carver (London: Central Banking Publications, 2011). Other studies have often excluded gold in their optimisation analysis for example: see Elias Papaioannou, Richard Portes and Gregorios, “Optimal Currency Shares in International Reserves: The Impact of the Euro and the Prospects for the Dollar (NBER Working Paper no.12333, June 2006).
4. This issue was confronted recently in a paper that described ‘relative numéraire risk’ as the difference between the efficient frontiers achieved by examining the results of an optimisation in dollars against the results in the domestic currency. In assessing the efficiency of the dollar analysis against a Thai baht optimisation the study highlighted the issue that an optimal portfolio analyzed from one numéraire might not be optimal in another. See Poomjai Nacaskul “Relative Numéraire risk and currency

- allocation of sovereign portfolios, in *Sovereign Asset Management for a Post-Crisis World*, ed. Donghyun Park (London: Central Banking Publications, 2011).
5. Reserve Bank of Australia Foreign Reserves Management available from <http://www.rba.gov.au/mkt-operations/mgmt-foreign-curr/perf-measurment.html>, accessed in December of 2011.
  6. The analysis conducted in emerging market currencies resulted in no significant allocation to any one particular asset/currency as was found in the US dollar analysis, with its bias toward US dollar assets.
  7. IMF IFS and COFER statistics as of the third quarter of 2011
  8. The price of gold is “fixed” twice daily by the Market Making members of the London Bullion Market Association. The pm fix is considered the benchmark rate within the gold industry whereby many contracts are based on.
  9. Except in the case of Brazil and Indonesia where the study was started at January 2000 to avoid significant foreign exchange fluctuations between 1998 and 2000.
  10. If instead the extremely volatile period of the Asian crisis was included in this analysis the results would have been skewed toward higher gold allocations as volatility between currencies on dollar and euro assets would have been more pronounced. Further analysis could be done to examine an optimal portfolio in a tail-risk event, which would likely show strong performance by many of the reserve assets as most of them are considered safe haven assets.
  11. Bloomberg end-of-day foreign exchange rates were utilised in this study. Where an exchange rate was not available, the rate was calculated by taking the relevant exchange rates against the dollar.
  12. Future analysis could use expected returns however given the optimisation method (See item 13), minor changes in return assumptions actually have a limited impact in the model results.
  13. The selection of 4% is consistent with marginal outperformance of gold over inflation of between 1% or 2% over a long-term horizon against inflation , which is estimated to be between 2% and 3% in dollar terms.
  14. See Harry M. Markowitz interview with Richard O. Michaud, *Journal of Investment Management*, Vol. 9, No. 4, 2011, 1–9. “JOIM Conference Series San Diego, March 6, 2011, Conference Summaries.”
  15. The advantage of using Michaud’s methodology lies in the fact that by resampling, the optimal weights diminish their dependence on the average returns, volatility and correlations used as assumptions of future performance. It is equivalent to consider a point estimate versus a confidence interval. The point estimate can be unbiased and consistent but it gives no sense of certainty. Instead, a confidence interval summarises both the best guess on what the parameter value is but also what other possible values it can take. Similarly, the Resampled Efficient Frontier allows for the estimation of confidence intervals around the optimal weights that would deliver the maximum return for a given level of risk.
  16. Since the information ratio for US agencies was higher than US Treasuries, the Barclays Capital US agencies aggregate was constrained to 25% to ensure that a large allocation in US dollar assets was not overly weighted toward US agencies which would be inconsistent with the generally the accepted view on central bank holdings.
  17. The “highest risk portfolios” are not included as the results were largely not significant and as central banks are unlikely to choose a high risk portfolio.
  18. The *Central Bank Directory* lists 160 central banks and 17 national central banks of the eurosystem. Of these 177, 118 central banks hold gold according to the IMF’s IFS statistics.
  19. Allocations for other assets (ie. US Treasuries, US agencies, etc) were also fairly indistinguishable between renminbi and dollar optimizations.
  20. See IMF article IV staff reports that typically discuss exchange rate flexibility for Poland as of July 2011 and Korea as of August 2011. Also see Report to Congress on International Economic and Exchange Rate Policies, US Treasury Department, February 2011.
  21. The NFA efficient frontier does not follow the typical concave output of a classical Markowitz efficient frontier due to the re-sampling technique.

22. Gold was statistically significant in 47 of 51 output portfolios at the 25% percentile level or at a 75% confidence level.
23. The majority of the results were significant at the 5% level. Furthermore, the minimum risk portfolios for seven of the nine currencies were statistically significantly different from the minimum risk portfolio conducted in US dollar terms. Only the Korean won and Polish zloty portfolios were not statistically significantly different, which may in part be due to the volatility smoothing of the Korean won and the strong relationship that the Polish zloty shares with the euro. See Note above.
24. As illustrated in Figure 5.8, the optimal range of gold allocations is skewed to lower values which is why the dotted line is longer above the median portfolio.
25. MXNXAU is the common approach to quoting currencies, with MXN signifying Mexican peso and XAU signifying gold, thus gold in Mexican pesos.
26. Correlation computed utilising the daily gold price and dollar trade weighted index sourced from Bloomberg, using monthly data between 2000 and 2011.