Exchange rate targeting and gold demand by central banks

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ABSTRACT

This paper explores the role of gold holdings in the composition of foreign exchange reserves that would be compatible with a central bank policy that targets the exchange rate. To this end, the paper develops an analytical model and performs a numerical analysis of the shadow price of the exchange rate target. The shadow price is treated as a sacrifice of target precision incurred when the monetary authority chooses one more unit of variance, which is a proxy for the precautionary motive for holding international reserves. The simulations indicate a two-regime demand for gold. The multiple equilibria results indicate that increasing the demand for gold from 0 to 21 percent leads to a lower but unstable policy sacrifice. The next minimum sacrifice – probably associated with economies of scale of large gold holdings – occurs approximately at around 40 to 60 percent of gold in the reserve portfolio. These results, therefore, indicate a wide range of possibilities for a central bank targeting the exchange rate to vary its demand for gold. Moreover, the results suggest that the ability to target the exchange rate is unaffected by the higher volatility of monthly returns on gold.

KEY WORDS: exchange rate anchor, international reserves, gold, emerging economies

1. INTRODUCTION

The question of the optimal level of foreign exchange reserves has been widely researched in the literature[1]. The issue speaks to the adequacy of reserves and the different reasons for holding reserves. Less visible is also the question of the optimal composition of foreign exchange reserves (Ben-Bassat 1980, Papaioannou et al. 2006). Here researchers are particularly concerned with the optimal combination of dollars, euros and other currencies. Relating to the issue of optimal composition is the question of the competitive relationship among anchor currencies, such as for instance whether the renminbi would erode the dollar's share as the primary preserve currency (Dobson and Masson 2009); and the associated question of the optimal number of

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[1] See Bahmani-Oskooee and Brown (2002), Aizenman and Lee (2007), Beck and Weber (2011), and Moore and Glean (2015) for comprehensive discussion of factors determining the optimal level of international reserves. Beck and Weber also study the connection between optimal level and the diversification of foreign exchange reserves.

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global anchor currencies (Kocenda et al. 2008). This paper falls under the second question relating to the composition international reserves. The paper makes a clear contribution to the literature by exploring central banks' demand for gold, as part of the composition of international reserves, under an exchange rate anchor or target. To the best of our knowledge, we are not aware that this question has been addressed in the literature, particularly within the context of exchange rate targeting.

It is intuitive that a central bank, which holds foreign currency reserves, usually demands a composition of assets such as US Treasuries, gold and other secondary reserve currencies. Moreover, when an exchange rate anchor guides monetary policy, the monetary authority has to demand adequate international reserves that serve to deter capital flight and minimize a currency crisis scenario (Kato et al. 2017). The purpose of this paper, therefore, is to examine what percentage shares of gold the central bank could demand relative to dollar assets without sacrificing the policy target.

We outline a model comprising of gold and US Treasures for three reasons. Firstly, in a recent opinion piece, Rogoff (2016) argues for emerging-market central banks to demand more gold and fewer dollar assets such as Treasury bills. According to Rogoff, this policy would increase the yield on Treasuries and the price of gold, thereby serving to rebalance central banks' international reserves. In addition, a recent comprehensive review of the literature on the financial economics of gold notes that the optimal percentage for private portfolios to be around 10 percent actual gold and shares of companies mining gold (O'Connor et al. 2015). However, central banks hardly ever hold private stocks, much less the stocks of gold companies.

Meanwhile, using the Markowitz mean-variance portfolio model, Gülseven and Özgün (2016) study household demand for gold in Turkey. They found that if Islamic investment rules and inflation are taken into account, households could demand as much as 50 percent gold in an investment portfolio[2]. Moreover, Chen et al. (2014, p. 2562) observe that there is no direct answer to the question of how much gold is appropriate for a central bank to demand, let alone studying the issue when the monetary authority targets the exchange rate. Secondly, a two-asset model greatly simplifies the mathematics without sacrificing crucial insights. Thirdly, we do not believe that a model of higher dimension would change substantially the results of this paper.

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[2] Using a panel regression model, Starr and Tran (2008) estimate the determinants of individual demand for gold. They found that limited financial development, cultural valuation and precautionary motive determine the demand for gold.

We think it is important to focus our attention on the demand for gold by central banks within the context of an exchange rate anchor given the growing tendency for countries to shift towards some kind of exchange rate target and away from flexible arrangements (IMF 2014). This implies that a growing number of countries utilize the exchange rate as the anchor of monetary policy, as the IMF report indicates. On the other hand, inflation targeting is often associated with a flexible exchange rate system, which does not require explicit targeting a level of foreign exchange reserves. An exchange rate anchor could also reduce the incidence of capital flight, as modeled by Kato et al. (2017) using a non-linear framework.

The paper is structured as follows. Section 2 presents descriptive statistics that present context and are useful for the numerical results. Section 3 outlines a foreign exchange market in which exchange rate targeting is the primary policy. Section 4 sets up the central bank's optimization problem. Section 5 presents the numerical simulations and interprets the results, while Section 6 concludes the study.

2. BACKGROUND INFORMATION

Table 1 presents the tonnes and percent shares of gold held as international reserves for several advanced and emerging economies. The advanced economies such as United States, France, Italy, Germany and Netherlands tend to hold the largest shares of gold, possibly owing to the legacy of the Bretton Woods System. However, the United Kingdom only has 9 percent of gold as foreign reserves. Japan holds approximately 2.5 percent of reserves in gold. In general, the emerging economies and developing countries tend to hold far less gold with the exception of Venezuela, which holds 66.8 percent gold as share of total reserves. The European Central Bank has around 27.2 per cent[3]. India holds around 6.3 percent while China has approximately 2.3 percent. On the relatively higher end for emerging economies – but not at the level of Venezuela – are Pakistan (13.3%), Russia (15.6%), South Africa (11%) and Turkey (17.2%). Small open economies such as Haiti, Mauritius, Singapore and Trinidad and Tobago tend to hold less than 10 per cent.

Table 2 indicates the descriptive statistics for US Treasury yields and gold returns using monthly data for the period from January 1998 to November 2016. The study is done over this period mainly to coincide with the great build-up of foreign reserves after the Asian financial

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[3] Note, the Euro-zone members maintain their foreign exchange reserves via National Central Banks holdings of gold and/or specific currencies, while being part of The European System of Central Banks.

crisis, as studied by Aizenman and Turnovsky (2002). The average return of 2.02 per cent on Treasuries is higher than that the 0.624 per cent return on gold. The yield on Treasury bills is calculated by averaging the US 3-month and 6-month Treasury yields. Moreover, there is a lot more variation associated with the return on gold. The smaller coefficient of variation of 1.01 associated with Treasury yields indicates the lower variability compared with 6.06 for gold returns. The correlation coefficient between gold returns and Treasury yields is quite small at 0.012 or 1.2 per cent.

Table 1   Official gold holding of selected countries as at June 2016

Country	Metric tons	Percent of FX reserves	Country	Metric tons	Percent of FX reserves
Brazil	67.2	0.8%	Netherlands	612.5	62.3%
China	1,808.3	2.3%	Pakistan	64.5	13.3%
Egypt	75.6	19.4%	Peru	34.7	2.3%
European Central Bank	504.8	27.2%	Russia	1,476.6	15.6%
France	2,435.7	64.5%	Saudi Arabia	322.9	2.2%
Germany	3,381.0	69.3%	Singapore	127.4	2.1%
Ghana	8.7	7.8%	South Africa	125.2	11.0%
Haiti	1.8	3.7%	Switzerland	1,040.0	6.6%
India	557.8	6.3%	Taiwan	422.7	3.9%
Indonesia	78.1	3.0%	Thailand	152.4	3.4%
Italy	2,451.8	68.6%	Trinidad and Tobago	1.9	0.8%
Japan	765.2	2.5%	Turkey	481.9	17.2%
Malaysia	36.4	1.5%	United Kingdom	310.3	9.0%
Mauritius	9.9	9.0%	United States	8,133.5	75.3%
Mexico	121.2	2.8%	Venezuela	230.1	66.8%

Source: World Gold Council

Table 2   Descriptive statistics of historical gold returns and Treasury yields

	Gold	US Treasuries
Mean	0.642%	2.021%
Median	0.288%	1.185%
Standard deviation	3.89	2.04
Coefficient of variation	6.06	1.01
Corr. coefficient	0.012	-

Source: Authors' calculations

3. THE DOMESTIC FOREIGN EXCHANGE MARKET

For the purpose of this paper, we assume the central bank is primarily concerned with targeting the exchange rate. It seeks to minimize the difference between the market's perceived or expected exchange rate and the target. The exchange rate regime may take the form of a conventional peg as in the case of The Bahamas, Barbados, Belize, Fiji, Namibia, CEMAC[4] countries and numerous others; a form of crawling-peg as in China or Botswana; a stabilized arrangement as in Bangladesh, Guyana, Singapore and numerous others (IMF 2014). Large appreciations can squeeze the tradable sector or depreciations could severely influence balance sheets and production when a significant number of domestic contracts are denominated in a foreign currency. Moreover, invoicing of exports and imports in a foreign currency could impede the ability of small open economies to adjust after a steep exchange rate devaluation (Golberg and Tille 2006). The central bank, therefore, intervenes in the domestic foreign exchange market in order to smooth out disruptive appreciations or punishing depreciations (Blanchard, Dell'Ariccia and Mauro 2010).

The loss function, which the monetary authority minimizes, can be expressed as follows

$$L = (S^E - S^T)^2 \qquad (1)$$

Where S^E is equal to the market's expected or perceived exchange rate and S^T is the central bank's anchor or target rate. The exchange rate is expressed as indirect quote in which units of domestic currency is divided by one unit of the US dollar (hereafter the dollar). Hence, an increase represents a depreciation or devaluation of the national currency relative to the dollar, while a decrease represents an appreciation. Let us assume the following: (i) when $S^E < S^T$ the market is expressing confidence in the target rate and reflects that the central bank has enough foreign reserves (F) relative to the target level (F^T); that is, $F > F^T$. The target level of foreign reserves is typically expressed as months of import cover (Moore and Glean 2015). (ii) When $S^E > S^T$ the market is expecting a depreciation or devaluation. This implies $F < F^T$, implying the central bank does not have enough of international reserves to defend credibly the anchor[5]. (iii)

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[4] CEMAC means Central African Economic and Monetary Community.

[5] It is possible to make F^T and F endogenous to other variables such as fiscal policy or a monetary policy action. We do not believe this is necessary for the task at hand in this paper. However, this is one extension to have a direct application of the model to country case studies. This paper provides a general framework for studying the question of central bank gold demand under exchange rate targeting.

When $S^E = S^T$ the domestic foreign exchange market is in equilibrium and this is consistent with $F = F^T$. This allows us to re-express the central bank's loss function as

$$L = (F - F^T)^2 \qquad (2)$$

Let us assume that aggregate market expectation is formed as follows

$$S^E = \pi S_D^E + (1 - \pi) S_A^E \qquad (3)$$

In equation 3, π equals the foreign exchange market's subjective or calculated short-run probability of depreciation or devaluation, while $1 - \pi$ indicates the market's short-term probability of an appreciation and a neutral position in which there is neither an appreciation nor depreciation. Although this probability could be subjective or objective based on some kind of model forecast, it is a short-run measure that can change frequently based on the emergence of new information.

In contrast, equations 4 and 5, respectively, indicate the long-term market and societal perception of depreciation (or policy devaluation) and appreciation as a function of $F - F^T$. For simplicity, assume both equations have the same positive constant ϕ. However, the values for θ_1 and θ_2 indicate different degrees of sensitivity to depreciation (or policy devaluation) and appreciation, respectively.

$$S_D^E = \phi + \theta_1(F - F^T) \qquad (4)$$

$$S_A^E = \phi - \theta_2(F - F^T) \qquad (5)$$

These parameters measure the long-term sensitivity of a society's or foreign exchange market's perception of depreciation or appreciation given the central bank's holdings of foreign reserves relative to target. In many small open economies, θ_1 would tend to be greater than θ_2 reflecting the higher societal aversion to devaluation[6].

This basic idea is sketched in Figure 1, which assumes the absolute value of the parameter of depreciation is greater than that of appreciation. The diagram is more consistent with the notion that the society is more sensitive to devaluation and know that appreciation seldom ever occur. However, it is general enough to account for the long-term sensitivity of appreciation. We would expect that the participants in the long-established fixed exchange rate

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[6] Throughout this paper, we use the term society to emphasize that in small open economies, particularly developing countries, the exchange rate is a much more than a market variable. The exchange rate is the most important price facing everyone.

systems of, for example, the Caribbean and Africa have a long-term aversion to devaluation and would seldom expect appreciations, likely the result of a social consensus in which market participants prefer a stable exchange rate system (Blackman 1998, Williams 2006).

Figure 1   Flexible long-term devaluations and sticky long-term appreciations
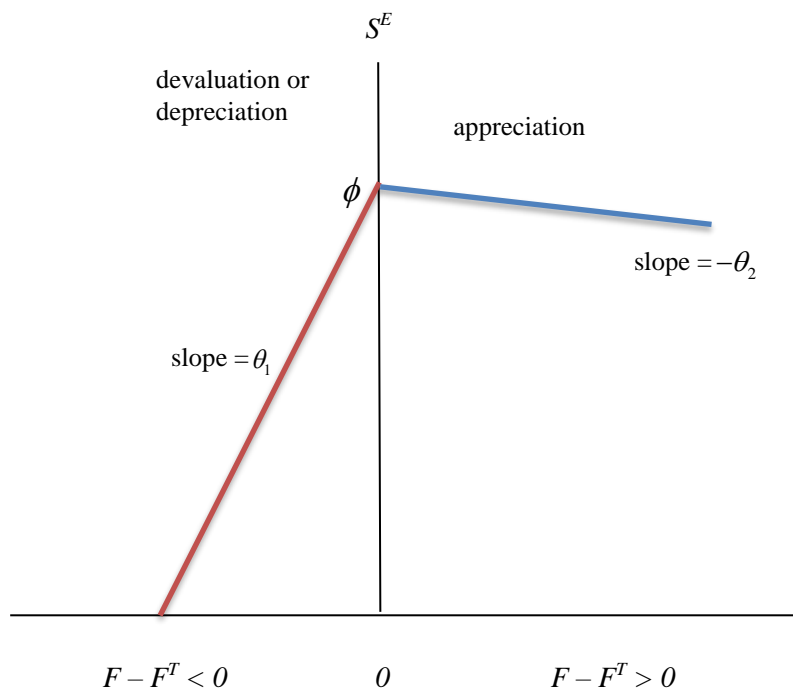
Such a perception is not surprising since the imports and exports of many economies are invoiced in dollars. This results in significant exchange rate pass through into prices for small open economies. In addition, devaluation of national currencies are less likely to result in an expansion of exports when most exports are invoiced in dollars[7]. Therefore, we can say the foreign exchange market is characterized by flexible long-run depreciations and sticky long-term appreciations. The respective slopes as illustrated by Figure 1 measure the relative degree of sensitivity. The model, however, is general enough for studying relatively more flexible long-term perception of appreciations. If the society and market prefer a completely flexible exchange

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[7] Looking at the issue of invoicing and trade adjustments, Goldberg and Tille (2006) explain how global invoicing in the dollar dampens the exchange-rate pass through for the United States but amplifies it for the rest of the world. A depreciation of the dollar, however, is more likely to boost American exports but not for the economies whose exports are invoiced in the dollar.

rate, we would expect $\theta_1 = \theta_2$ in absolute value. However, this does not mean there is a flexible regime since the central bank may pursue an exchange rate anchor.

Let us decompose the deviations of central bank's actual foreign reserves from target as follows

$$F - F^T = a_1(F - F^T)w_G + a_2(F - F^T)(1 - w_G) \tag{6}$$

The parameters a_1 and a_2, respectively, represent the speed of adjustment for foreign reserves held in gold versus US Treasuries. These include frictions and transaction costs that the central bank must bear as it rebalances its portfolio of gold and Treasuries. We expect higher transaction cost associated with holding gold. Higher transaction costs would be associated with less market making; therefore, we expect a smaller speed of adjustment in the gold versus market for Treasuries (that is, $a_1 < a_2$). The percent of foreign exchange reserves held as gold is w_G while the percent in Treasuries is $1 - w_G$ (note: $w_G + w_T = 1$).

Although the paper studies the percentage combination of gold relative to Treasures that could be ideal, the methodology can also be used to explore the combination of gold plus other currencies against US Treasuries. However, this would require having precise estimates of the relative weights of gold and less weighted reserve currencies such as the euro, sterling, yen and others versus the dollar. It is easier, however, to ascribe a higher transaction cost to gold compared with the various globally important currencies. There should not be a significant difference between the adjustment coefficients for reserves denominated in dollar versus the euro. It is for this reason we prefer to study the anchor currency – in this case the dollar – versus gold as this allows for the delineation of adjustment coefficients. Gold would have storage and other costs associated with demanding the asset. However, a large enough demand for gold would result in economies of scale by spreading the transaction costs.

Substituting equations 4, 5 and 6 into 3 and rearranging would yield the following equation

$$F - F^T = \frac{\phi - S^E}{[a_2(w_G - 1) - a_1 w_G][\pi(\theta_1 + \theta_2) - \theta_2]} \tag{7}$$

The framework proposed assume the central bank chooses w_G while minimizing the square of the difference between F and F^T while also considering the societal parameters, the market's expectation of devaluation or depreciation, and the higher transaction cost associated with

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demanding gold. Moreover, compounding the central bank's problem is the fact that there is greater volatility associated with the price of gold. Therefore, the loss function and the constraint function are given by equations 8 and 9, respectively.

$$L = (F - F^T)^2 = \frac{(\phi - S^E)^2}{\{[a_2(w_G - 1) - a_1 w_G][\pi(\theta_1 + \theta_2) - \theta_2]\}^2} \tag{8}$$

The variance of the two-asset portfolio is

$$\sigma_P^2 = w_G^2 \sigma_G^2 + (1 - w_G)^2 \sigma_T^2 + 2w_G(1 - w_G)\sigma_G \sigma_T \rho_{GT} \tag{9}$$

σ_G^2 indicates the historical variance of gold return and σ_T^2 represents the historical variance of the average Treasury yields. The correlation coefficient, calculated from historical data, is indicated by ρ_{GT}. The simulations that follow assume that the central bank's target of the exchange rate – that requires balancing ex post and ex ante foreign reserves – is constrained by the volatility introduced by adding gold to the portfolio of reserves. We think that using the portfolio volatility as the constraint to central banks' exchange rate management is consistent with the precautionary motive for demanding international reserves (Aizenman and Lee 2007).

4. THE CONSTRAINED GOLD DEMAND

The central bank seeks to choose a level of gold that minimizes the loss function subject to portfolio volatility. Let us write the optimization problem as follows

$$Z = (F - F^T)^2 + \lambda[\sigma_P^2 - w_G^2 \sigma_G^2 - (1 - w_G)^2 \sigma_T^2 - 2w_G(1 - w_G)\sigma_G \sigma_T \rho_{GT}] \tag{10}$$

The shadow price in this context is given by λ. For the purpose of this paper, the shadow price is interpreted as a sacrifice the central bank incurs when incurring one or more units of portfolio variance or volatility. In other words, λ measures the degree of the exchange rate target that the central bank has to sacrifice as it assumes higher volatility associated with demanding more gold in the portfolio. Table 2 clearly shows that the historical volatility of gold price is higher than that of US Treasury yields.

The partial derivative with respect to gold results in the following equation

$$\frac{\partial Z}{\partial w_G} = \frac{2(a_1 - a_2)(\phi - S^E)^2}{[a_2(w_G - 1) - a_1 w_G]^3[\theta_2 - \pi(\theta_1 + \theta_2)]^2} - 2\lambda[w_G \sigma_G^2 + (2w_G - 1)\sigma_G \sigma_T \rho_{GT} + (w_G - 1)\sigma_T^2] = 0 \tag{11}$$

Equation 11 suggests that we have to explore the demand for gold numerically given values for the various parameters of the model[8]. We know that the demand for gold can only take values from 0 to 100 percent, thereby enabling the simulation of the possible values for the policy sacrifice. Note that $a_2 > a_1$ given the higher transaction costs associated with demanding gold. The decision rule looks for whether there is a unique value of minimum policy sacrifice or if there is a range of possible values for λ over which the function is a minimum. We are also interested in whether the range of values increase or decrease significantly or gradually. If the sacrifice value is increasing or decreasing slowly, we could conclude that it is possible to demand gold over said range without significantly incurring or reducing policy sacrifice, respectively.

## 5. NUMERICAL ESTIMATES OF SACRIFICE AND DEMAND

The simulations are performed for two levels of exchange rate appreciation stickiness: $\theta_2 = -0.2$ and $\theta_2 = -0.6$. As Figure 1 indicates, the $\theta_2 = -0.6$ represents a greater tendency for appreciation (less stickiness) compared with $\theta_2 = -0.2$, which indicates a higher degree of stickiness. We set $\theta_1 = 1.6$ to reflect the stronger tendency of the market to prefer depreciation relative to appreciation. As noted earlier, given the transaction cost associated with holding gold, we expect $a_2 > a_1$. Higher transaction cost would diminish the level and number of market trades, thereby reducing the speed of adjustment of gold in the portfolio. Therefore, we set the following coefficients: $a_1 = 0.3$ and $a_2 = 0.8$. Finally, let $\phi = 5$ and $S^E = 2$. These values and those reported in Table 2 help to simulate the numerical estimates of policy sacrifice over the range of w_G from 0 percent to 100 percent.

Figure 2 presents the first simulation result for which the probability of devaluation is $\pi = 0.3$. The chart indicates a multiple regime demand for gold. The multiple regimes fall on the left and right side of the asymptote, which occurs at approximately 21.4 percent (the broken vertical line). The regime to the left of the asymptote is a disequilibrium regime in which the policy sacrifice declines monotonically over the range 0 percent to around 21 percent. We call this a disequilibrium regime because there is no stable percentage or a range of percentage values over which the policy sacrifice neither decreases nor increases precipitously. The disequilibrium

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[8] Appendix 1 includes the numerical evaluation of the bordered Hessian.

notwithstanding, the central bank could reduce its policy sacrifice by increasing the demand for gold from 0 percent to close to 21 percent, since the policy sacrifice decreases monotonically until it reaches close to the asymptote. It could be that a certain amount of economies of scale of gold must me reached before a more stable regime can be obtained.

Figure 2   Gold demand when probability of devaluation and depreciation is 0.3
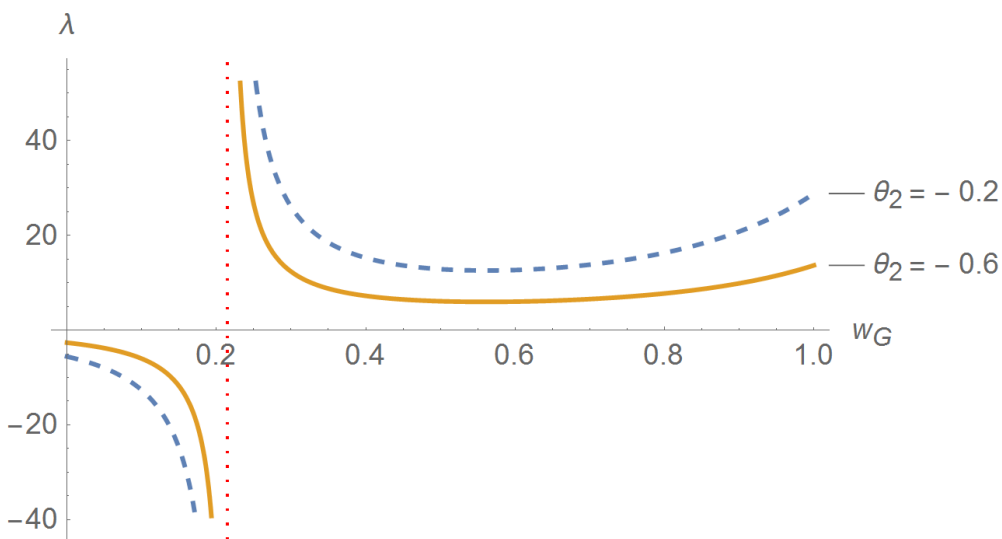
This is the case to the right of the asymptote. After 21.4 percent, the sacrifice declines precipitously, thereby implying that demanding gold would consistent with a more precise foreign exchange target. The policy sacrifice decreases until it reaches approximately 40 percent gold in the portfolio. This result is possibly consistent with the gains in economies of scale associated with holding larger quantities of gold. These scale economies might be responsible for the relatively more stable policy sacrifice over a range of possible percentage gold demand.

The policy sacrifice starts increasing only gently around 55 percent, implying that gold demand can increase over a wide range without a significant loss in ability to target the exchange rate. However, the rate of increase in the policy sacrifice is steeper after 55 percent for countries in which the preference for appreciation is smaller or alternatively the curve stays relatively flat over a wider range when the market (or society in general) has a higher response to appreciation. We think this is an intuitive result indicating that a more sticky appreciation provides a relatively smaller range of flat policy sacrifice, assuming the short-term likelihood of devaluation is held constant. According to the results, therefore, the demand for gold could increase without

incurring significantly greater sacrifice over the range 40 percent to around 60 percent. This is an interesting result given that gold has a higher historical volatility compared with Treasuries.

In addition, figure 2 indicates that a higher absolute value of θ_2 – a situation of greater long-term downward flexibility in the rate – causes the policy sacrifice to shift towards zero for the equilibrium resulting on the right side of the asymptote. This suggests that the greater the market's expectation of appreciation is, the less loss the central bank will incur. The result suggests that if the market is expecting a long-run appreciation, the same amount of gold results in less policy sacrifice loss. This further implies that there is greater credibility in the exchange rate anchor. Moreover, this would tend to be the case for countries whose exports and imports are invoiced mainly in a foreign currency such as the dollar, even as they possess a national currency. In these countries, policy makers and the general society tend to be more concerned with currency devaluations (or precipitous depreciations) than appreciations[9].

The opposite occurs in the disequilibrium regime on the left side of the asymptote. The higher the appreciation coefficient, in absolute measure, results in a larger loss as the same amount of gold results in a larger sacrifice. This result could possibly be associated with countries with much softer exchange rate targets, such as countries with a history of non-fixed exchange rate that results in periodic adjustments. In this instance, the maximum amount of gold should be around 21 percent for countries with historically more flexible targets. It would imply that such a society and foreign exchange market has a greater tolerance of depreciations, possibly because a larger percentage of imports and exports are expressed in the national currency. In these countries, a depreciation would provide the advantage of adjusting the current account balance. In the former case, the results could be more relevant to countries in which the depreciation or devaluation does not help to correct the current account; instead, it leads to higher import cost of production, destabilizing output losses and strong exchange-rate pass through to domestic inflation.

Figure 3 indicates the outcome when the probability of devaluation rises to 0.8. Interestingly, the higher short-term probability of devaluation dampens the curve-separating effect of the society's long-term sensitivity to devaluation (or depreciation) versus appreciation. In other words, the higher the short-term probability of devaluation or depreciation, the smaller is

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[9] It is possible that a social consensus can develop whereby important segments of a society prefer a pegged exchange rate, as would be the case for several Caribbean economies (Williams 2006).

the distance between the two sacrifice curves. The probability of devaluation is a short-term measure of uncertainty that would change to reflect sudden perceptions and frenzies given an updated information set, whether unfounded or credible.

However, there is still a wide range of percentage demand over which the policy sacrifice is relatively stable. For the equilibrium regime occurring to the right of the asymptote, the demand for gold could be a value within the range 40 percent to 60 percent without incurring significant loss in terms of policy sacrifice. The disequilibrium regime occurring to the left of the asymptote implies increasing the demand for gold until around 21 percent would result in lower policy sacrifice; but there is no unique or stable value of policy sacrifice under the disequilibrium regime.

Figure 3   Gold demand when probability of devaluation and depreciation equals 0.8
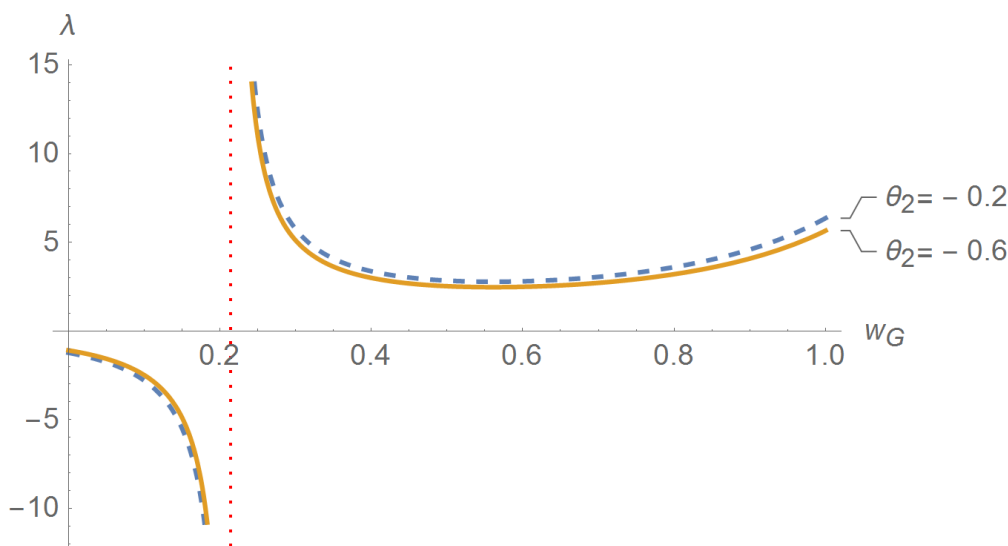
6. CONCLUSION

The analytical model and numerical simulations derived in this paper suggest that a central bank, which pursues an exchange rate target, could increase its demand for gold over a relatively wide range of percentage values without sacrificing its ability to target the exchange rate. Moreover, our derivations indicate that the higher volatility that gold brings to the asset composition of international reserves does not adversely affect the monetary authority's ability to target the

exchange rate. In other words, the exchange rate target is independent of the volatility of the assets making up the central bank portfolio of international reserves.

As the short-run probability of devaluation or depreciation rises, the distance between the sacrifice curves narrows, thereby reflecting that the short-term outlook is outweighing the parameter measuring the market's (or society's) long-term sensitivity to a devaluation. This latter result is particularly relevant to economies that invoice their exports and imports in the American dollar or euro. On the other hand, as the short-term probability of devaluation declines, the long-term sensitivity to devaluation becomes more important driving a wedge between the sacrifice curves. These findings suggest that demanding more gold in the composition of international reserves is not necessarily detrimental to maintaining an exchange rate anchor.

Although the paper examined the percentage combination of gold relative to Treasures in a general context, the methodology could also be applied to country case studies once the various parameters are estimated. The model of a flexible and a sticky regime of exchange rate perception could be integrated into the appropriate equation of motion for dynamic analyses.

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APPENDIX 1

The bordered Hessian for the second-order condition is

$$H = \begin{pmatrix} 0 & \dfrac{d\sigma_P^2}{dw_G} \\ \dfrac{d\sigma_P^2}{dw_G} & \dfrac{\partial^2 Z}{\partial w_G^2} \end{pmatrix}$$

Where,

$$\frac{d\sigma_P^2}{dw_G} = -2[(\sigma_G \rho_{GT} - \sigma_T)\sigma_T + w_G(\sigma_G^2 - 2\sigma_G \sigma_T \rho_{GT} + \sigma_T^2)]$$

and

$$\frac{\partial^2 Z}{\partial w_G^2} = \frac{6(a_1 - a_2)(\phi - S^E)^2}{(a_2 + a_1 w_G - a_2 w_G)^4 [\theta_2 - \pi(\theta_1 + \theta_2)]^2} - 2\lambda(\sigma_G^2 + \sigma_T^2 - 2\sigma_G \sigma_T \rho_{GT})$$

A numerical evaluation of the bordered Hessian for the same values used previously and for

$\pi = 0.8$ (a lower probability does not change the result), $\phi = 5$ and $S^E = 2$ results in

$$H = \begin{pmatrix} 0 & 8.21 - 38.29 w_G \\ 8.21 - 38.29 w_G & \dfrac{5400}{6.1^2 (1.6 - w_G)^4} - 38.28\lambda \end{pmatrix}$$

Therefore,

$$\det H = -(8.21 - 38.29 w_G)^2$$

Evaluating the determinant over values for w_G from 0 to 1 would give only negative numbers, except at the asymptote where the determinant is 0. Figure A1 shows the graph of the determinant evaluated for w_G from 0 to 1.

Figure A1   Numerical evaluation of the determinants of the bordered Hessian