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## *Strategic Asset Allocation of a Reserves' Portfolio: Hedging Against Shocks*

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*Banco Central de la República Argentina*

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# Non-Technical Summary

## Research Question

Central bank reserves function as a precautionary saving for countries to mitigate exposure and vulnerability to the volatility of capital flows. Emerging Markets have been the most exposed countries. After being impacted from several crises, they built up for nearly two decades large war-chests of international reserves as a self-insurance mechanism. With large amounts of international reserves accumulated, most central banks have been seeking to enhance the yield and diversification of their investments in an effort to reduce the cost of holding reserves, given the low interest rate environment. The traditional mean-variance framework used to construct an efficient portfolio for the investment of central bank reserves could, nevertheless, be enhanced. It is important to distinguish a central bank reserves´ portfolio from other investment funds and consider the true purpose of holding international reserves, to prevent doubling up risks when investing central bank reserves.

## Contribution

We propose a portfolio construction framework where the objective does not only consider the return, volatility, and diversification between financial assets, but also how each asset contributes to increase the market value of international reserves when reserves are most needed (e.g. under stress scenarios). An index emulating external shocks is constructed to synthetize the positive and negative shocks to which emerging market economies are subject. This index is included in the portfolio construction process to expand the risk dimension to one where the volatility of international reserves is driven not only by the volatility of financial assets but also by the volatility caused from external shocks. This new dimension of risk allows to introduce in the portfolio construction of central bank reserves the hedge properties provided by some financial assets under stress scenarios, which is generally overlooked in the traditional mean-variance analysis. As a result, it brings into notice what dimensions of risk are worth taking, which asset classes it is worth diversifying into, and the analysis is extended into currencies, credit, and duration.

## Summary

There is value to include this kind of analysis for central banks, as it is a way to better understand the underlying risk factors of the national balance sheet, preventing to double up the main vulnerabilities of each country but also to have procyclical behaviors that would only exacerbate the challenges faced under stress scenarios (i.e. when reserves are more needed). There are risks that are worth to take when central banks are considering to increase the expected return of their reserves' portfolio, and risks that are not. A higher duration risk, for example, goes in the right direction due to the hedge properties provided by long-term bonds under stress scenarios. Such hedge properties are very important to help central banks to find their compensation for taking a higher duration risk, especially in the current low yield and term-premium scenario. The traditional portfolio construction approach generally overlooks the underlying risk factors. Same allocations are recommended to very different countries, with very different risk profiles and exposures in their national balance sheet. Some countries are more exposed to commodity prices, other countries to the volatility of capital flows. There are many risk factors that are relevant, especially for those countries more vulnerable to external shocks. These factors should play a role in the strategic asset allocation of the reserves' portfolio.

# STRATEGIC ASSET ALLOCATION OF A RESERVES' PORTFOLIO: HEDGING AGAINST SHOCKS

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## Abstract

*Central bank reserves function as a liquidity buffer to mitigate country exposure and vulnerability to external shocks. Emerging Market Economies are the countries most exposed to the volatility of capital flows and have usually preferred to build up large war-chests of international reserves as a self-insurance mechanism, as it is under their full discretion. Nevertheless, the standard practice of immobilizing large amounts of "cash" to insure against jumps in volatility and risk-aversion could be enhanced. The inclusion in the strategic asset allocation decision of external shocks´ hedging strategies, which may increase the market value of the reserves´ portfolio when reserves are more needed, can help to enhance the risk management of the national balance sheet. This paper presents a framework that seeks to enhance the strategic asset allocation of a central bank, by including in the portfolio construction the analysis of correlations between the reserves' portfolio and the country's main vulnerabilities to external shocks.*

## 1. Introduction

Central banks hold reserves for a variety of reasons, but mainly as a liquidity insurance to mitigate country exposure and vulnerability to external shocks.

For Emerging Market Economies (EMEs), the exposure to capital flows is high, as they are more dependent on external savings, resulting in persistent current account deficits. The funding of these deficits requires ongoing capital inflows, which can suddenly stop. As soon as a sudden-stop occurs, the country's current consumption capacity is reduced and the marginal value of an extra unit of reserves increases significantly.

Although some insurance arrangements (e.g. contingent credit lines and bilateral swap agreements) have helped to address their precautionary needs, EMEs countries have usually preferred to build up large war-chests of international reserves as a self-insurance mechanism, as it is under their full discretion.

But the standard practice of immobilizing large amounts of "cash" to insure against jumps in volatility and risk-aversion, even when optimally managed, had been gathered as expensive and incomplete. Caballero and Panageas (2004) concluded that this strategy is clearly inferior to one in which portfolios may include assets that are negatively correlated with external shocks.

In an oil-producing country, for example, a sharp drop in the oil price significantly affects the fiscal balance, consumption and growth of such country. Therefore, the correlation between the changes in the oil price

and the changes in the price of the financial assets' portfolio should not be ignored. Between two assets with the same expected return and risk, the strategic asset allocation should choose the asset having the lowest correlation with the main exposure and vulnerability of such country. Moreover, a sound sovereign risk management framework should try to avoid having any significant exposure to those shocks that are more damaging for the economy.

The introduction of external shocks in the strategic asset allocation decision of a central bank´s reserves portfolio may help to enhance the risk management of the national balance sheet, as discretionary portfolio decisions can affect the national risk profile[1].

Our paper presents a framework that seeks to enhance the strategic asset allocation decision of a central bank. Following the pioneering ideas of Caballero and Panageas (2004) and the model proposed in Gintschel and Scherer (2008), we use a synthetic asset to emulate the most relevant external shocks, which is then included in the optimization process to analyze the immunization provided by the reserves' portfolio to these macroeconomic risks. As a result, the optimization is run in a different risk-return framework, one where risk is not limited to the volatility of financial assets' portfolio but expanded to consider the volatility in the reserves portfolio caused by external shocks.

Once the definition of risk is expanded to include the volatility in the reserves portfolio caused by external shocks, there are very important changes in the composition of the efficient frontier. The optimization tends to give more preference to hedge assets like long-term bonds and, paradoxically, the greater the weight of these assets in the portfolio, the lower the volatility of the reserves portfolio due to the hedge provided.

But the implementation of these strategies in practice is not simple. An efficient strategy in terms of immunization will certainly be sub-optimal in terms of the traditional efficiency observed in the central bank's balance sheet, which may be exposed to greater volatility in the financial asset's portfolio and even to have negative returns. We use a Conditional Value-at-Risk (CVaR) limit to control such concerns and limit the volatility of the financial assets' portfolio.

In the first part of the paper we review the theoretical framework described in Caballero and Panageas (2004) to better understand the impact of sudden stops in the optimal allocation of central bank reserves (section 2), and we present the framework proposed based on the Gintschel and Scherer´s model (section 3). In the second part of the paper (section 4) we review how the implementation of this framework could impact the asset allocation of emerging market countries in Latin America. We first show the convenience to use this framework to incorporate certain features in the portfolio optimization of a central bank, in terms of currencies, duration, credit ratings and asset classes; and we then show the contrasting results for the strategic asset allocation decision when the definition of risk is expanded to consider the volatility in the reserves' portfolio caused by external shocks. Finally, in the third part of the paper (section 5) we conclude with our final remarks.

[1] Gray and Malone (2008) find that the sovereign has a special role to perform as a manager of sovereign risk: both to manage its own risks, but also to facilitate efficient and effective risk management in other parts of the economy. Indeed, central banks are usually exposed to contingent liabilities as safeguards of financial stability due to the interconnections between the balance sheets of the different sectors (corporates, households, financial sector, government, and the monetary authority).

## 2. Theoretical Framework

The microeconomic frictions behind sudden stops and the impact in the optimal allocation of central bank reserves is presented in Caballero and Panageas (2004) through the assumption that there are three type of agents: EMEs, specialist investors, and the world capital markets at large.

EMEs are countries in the pre-development phase that would like to borrow against its post-development income, as its future income is significantly higher than its current income. Therefore, they run persistent current account deficits but have great difficulty in pledging future income to finance these deficits.

Potential financiers are split into world capital markets at large, and specialists. Specialists are risk neutral investors that have developed some expertise and connections in the country. During normal times, they engage in "swap-like" contracts with the country where they commit to provide resources in exchange for receiving a promise to a stream of payments if development arrives. But specialists themselves are subject to shocks that limit their ability to commit to deliver resources. These shocks trigger a period of significantly reduced capital inflows (i.e. risk-off scenarios). The beginning of this period is the sudden stop itself, when specialists are unable to rollover all their explicit or implicit short term commitments, but it can continue even after specialists recover, as countries have to rebuild their international collateral.

The country would like to insulate its current account financing from these sudden stops, but it cannot do so with its specialists since they are constrained during these events. Resorting to the world capital markets after the sudden stop takes place does not work either, since the country has very limited credibility with non-specialists.

Nevertheless, world capital markets can still be used ex-ante, as long as contracts and investments are made contingent on variables that do not require emerging markets' knowledge.

Therefore, the strategic asset allocation may help central banks to transfer reserves to sudden stop scenarios.

Caballero and Panageas assume a central bank's objective that has the following form:

$$\max_{R_0,\pi} -\frac{\alpha}{2}E[(R_1 - K - 1\{SS\}Z)^2]$$

where $R_1$ denotes total reserves at date 1, $K \geqslant 0$ is a target level of reserves at date 1, and $1\{SS\}Z$ is a term composed of two terms: an indicator function $1\{SS\}$, that becomes 1 during a sudden stop $\{SS\}$ and is 0 otherwise, and a constant $Z > 0$, that controls the need for funds during the sudden stop.

They solve this problem subject to:

$$R_0 = \pi P_0 + B_0$$

$$R_1 = B_1 + \pi P_1$$

where $R_0$ is the initial level of reserves, $\pi$ is the amount of risky securities held by the central bank, $P_0$ is the price of such securities, $P_1$ is the (stochastic) payoff of these assets at t = 1, and $B_0$ is the amount of uncontingent bonds held by the central bank, whose interest rate is fixed to 0 for simplicity, so that $B_1$=$B_0$ and $R_1 = R_0 + \pi(P_1 - P_0)$

They show that the first order conditions with respect to $R_0$ and $\pi$ yield:

$$R_0 = K + \Pr(SS)\, Z$$

$$\pi = Z \frac{Cov(1\{SS\}, P_1)}{Var(P_1)}$$

Based on these conditions, they discuss three different solutions that are of special interest for central banks:

1) No Hedging:

   The first alternative assumes a no-hedging ($\pi = 0$) decision, which is not far from what central banks do in practice. With no hedging $B_0 = R_0 = K + \Pr(SS)\, Z$ and, therefore, the possibility of a sudden stop induces the country to hold reserves beyond the target level $K$.

2) Arrow-Debreu Securities:

   The second alternative is the opposite one. Assuming there were perfect Arrow-Debreu securities[2] (and fair pricing), and/or contracts could be written contingent on the sudden stop events, then perfect hedging would be possible and, therefore, in the special case where $K$ = 0 (corresponding to the case where the country finds it optimal to hold no reserves in the absence of sudden stops) a central bank would be induced to invest 100% of its reserve assets in such Arrow-Debreu securities.

3) The intermediate case:

   The third alternative is an intermediate one. In reality, as one neither observes Arrow-Debreu securities nor does observe contracts written contingent on the sudden stop (at least in an amount sufficient to insulate the country from it), Caballero and Panageas propose that a proxy hedging, through contracts that are correlated with sudden stops, but not perfectly, could function as good substitutes for the idealized Arrow-Debreu securities (paying 1 when some proxy event happens, and zero otherwise). One of such proxy events found by these authors is the jump of the VIX index[3], which they show that has a strong correlation with the incidence of sudden stops.

The framework we present in this paper is a proxy hedging that seeks to enhance the immunization from external shocks through the strategic asset allocation of central banks.

Following the model proposed in Gintschel and Scherer (2008), we consider the volatility of the reserves portfolio in a risk-expanded dimension, where the reserves portfolio fluctuates due to the changes in the market value of the financial assets (traditional scope) but also as a result of external shocks. As a result,

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[2] An Arrow-Debreu security is an asset that pays:
1 if $SS$ = 1
0 if $SS$ = 0

[3] The Cboe Volatility Index® (VIX® Index) is considered by many to be the world's premier barometer of equity market volatility. The VIX Index is based on real-time prices of options on the S&P 500® Index (SPX) and is designed to reflect investors' consensus view of future (30-day) expected stock market volatility. The VIX Index is often referred to as the market's "fear gauge" (for further references see http://www.cboe.com/products/vix-index-volatility).

we include in the construction of the efficient frontier the risk-reduction benefits of those investment strategies that are negatively correlated with the main external shocks and/or vulnerabilities of the country.

Gintschel and Scherer (2008) show that choosing a portfolio along the efficient frontier, which is typically viewed as the key task in asset allocation, is relatively unimportant compared to the hedge decision. Their work is an example of how risk stemming from nonfinancial assets can be hedged, at least partially, through financial assets. The key is exploiting the correlation between financial and non-financial assets to reduce the overall risk of the portfolio, compared to an allocation that considers only the correlation structure of the financial assets.

The framework we propose uses a synthetic asset to emulate the main shocks that could impact the reserves´ portfolio. Rather than looking at strategies that could generate large payoffs but could also be exposed to some important challenges in terms of cost, size, and the credit risk of such payoffs[4], it seeks to enhance the risk management framework of the sovereign balance sheet, which can help countries to avoid "wrong-way risks"[5] in their strategic asset allocation of large reserve portfolios and reduce the probability of having "procyclical behaviors"[6].

## 3. The framework proposed

Reserve assets are usually the first line of defense for those countries that try to smooth the impact of external shocks in the domestic consumption. Foreign exchange intervention is quite common in emerging market countries, especially in those scenarios with high market volatility. Moreover, central banks typically provide explicit or implicit financial support to large financial institutions in the case of serious deposit runs, illiquidity, or insolvency.

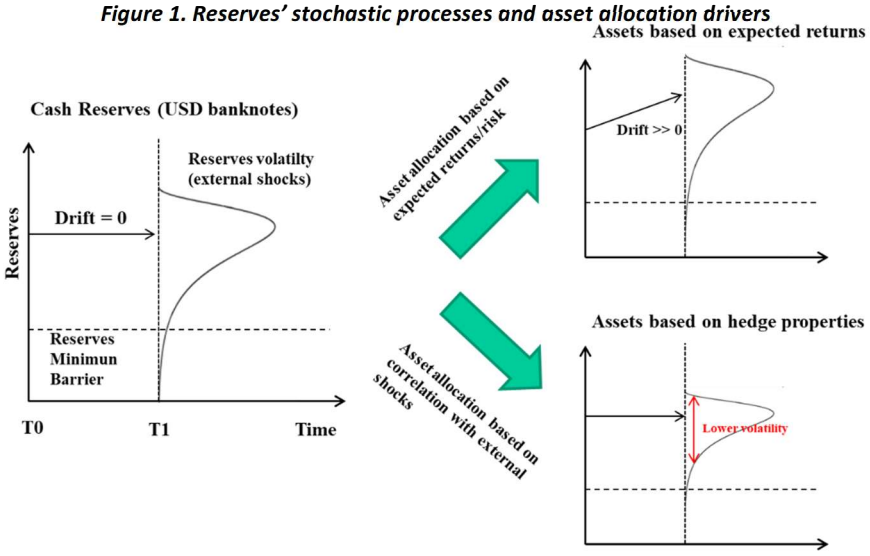
Therefore, external shocks are usually impacting the reserves portfolio. As shown in figure 1, even if a central bank would be investing its reserves portfolio in cash (i.e. US dollar banknotes) to avoid any exposure to market or credit risks (drift=0), it would end up having a stochastic process and volatility in the reserves portfolio as a result of the foreign exchange intervention and/or other operations performed to safeguard financial stability.

[4] Large payoffs could be challenging for any private insurer and would be triggered during the most unwelcomed scenarios for such insurers, increasing the risks of having further disruptions if such payoff creates a liquidity problem in an insurer that is a systemically important institution

[5] Wrong-way risk is defined by the International Swaps and Derivatives Association (ISDA) as the risk that occurs when "exposure to a counterparty is adversely correlated with the credit quality of that counterparty". In short, it arises when default risk and credit exposure increase together. In this paper we use "wrong-way risk" in a different way. We use it to define such scenarios where the risk of having a drop in the market value of the reserves portfolio increase when reserves are more needed, i.e. when the marginal utility of an extra unit of reserves increases significantly.

[6] Pihlman et al (2010) show the procyclical behavior in central bank reserve management during the 2007-2008 global financial crisis

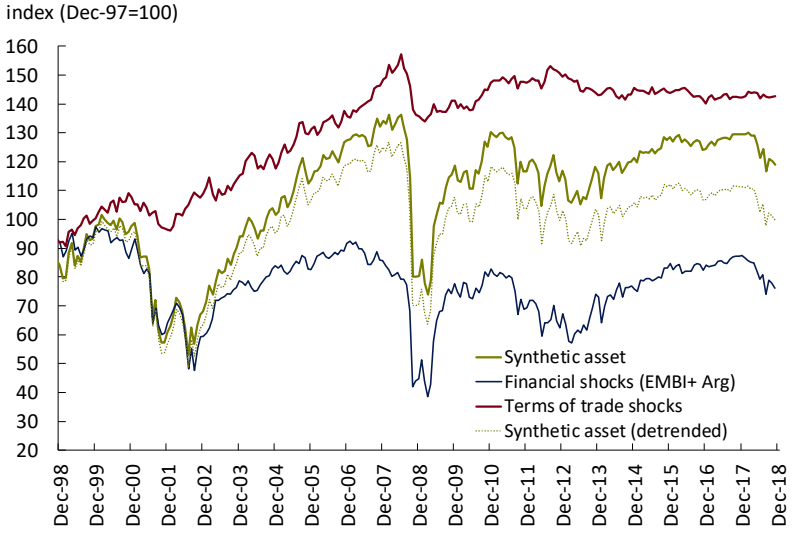
***Figure 1. Reserves' stochastic processes and asset allocation drivers***




The framework we propose expands the definition of the volatility of the reserves portfolio to include the impact of external shocks and the correlation between the reserves portfolio and such shocks. As shown in figure 1, we propose a strategic asset allocation decision that is based on both the expected returns and risk of the financial assets' portfolio, but also on the hedge properties and risk reduction benefits that some financial assets may have in those scenarios when reserves are more needed.

The impact of external shocks is modeled through an index that emulates the most common sources of external vulnerability. In the case of Argentina, for example, the two most common sources of external vulnerability are real terms of trade shocks and financial shocks.

***Figure 2. Synthetic Asset (cumulative external shocks for Argentina)*** [7]




These shocks are quantified into a time series of cumulative wealth shocks by constructing a synthetic asset. The construction of this synthetic asset shock follows four consecutive steps:

[7] See Sturzenegger (2018)

i. Selecting the indexes that proxy the most common external shocks
ii. Quantifying the size and impact of these shocks
iii. Normalizing the shocks by the size of reserves, to convert the shocks in "returns" of an asset
iv. Constructing an index based on the compounding of the asset "returns", which is then detrended to have a zero expected return for this synthetic asset shock (to focus only in the correlation of this synthetic asset with the financial assets' portfolio).

This synthetic asset is then incorporated into an optimization framework similar to the one proposed in Gintschel and Scherer (2008). In this case, it seeks to minimize the variance of a portfolio of reserves $Var(r)$ allocating an omega $\omega$ proportion to a synthetic asset and the remaining $(1-\omega)$ to a portfolio of financial assets whose weights are described by the vector $w$:

$$min\ Var(r) = \omega^2\sigma^2_{Act.Sint.} + (1-\omega)^2 w^T \Sigma w + 2\omega(1-\omega)\sigma^2_{Act.Sint.} w^T \beta$$

The variance to be minimized is composed of a first term that reflects the volatility of the synthetic asset, a second term that reflects the volatility of the portfolio of financial assets $w^T \Sigma w$ and a third term $2\omega(1-\omega)\sigma^2_{Act.Sint.} w^T \beta$ which reflects the correlation between the synthetic asset and the portfolio of financial assets. The term $\beta$ contains the sensitivities of each financial asset in relation to the synthetic asset.

In the framework we implement, the problem is solved subject to the following restrictions:

$$1^T w = 1$$
$$E(r_i)^T w = \mu$$
$$w_i \geq 0\ \forall w_i$$
$$CVaR_{95\%}(r^T w) < CVaR_{limit\ 95\%}$$

That is, the optimization must comply that the sum of the weights assigned to each asset total 100%, that the assets must have a non-negative weight (short sales are not permitted), that the financial assets have the expected yield ($\mu$) that has been projected based on their risk factors, and that changes in the market value of the portfolio of financial assets does not exceed a given threshold set in terms of its Conditional Value-at-Risk ($CVaR$).

These restrictions highlight two important components that are worth to mention:

1- Expected returns are estimated based on risk factors' projection.
2- The eligible portfolios of financial assets are limited to those that comply with the tolerance for the market risk of such portfolios.

Setting a limit in terms of the market risk of such portfolio is a very important element of this framework, as it permits the central bank to keep its balance sheet volatility under control.

Indeed, central banks usually prefer to focus on their own balance sheet, trying to avoid having any headline or reputational risks. Even if there are assets (i.e. long term US Treasuries) that perform well when reserves are more needed, and that could be attractive to increase the yield and drift of the reserves

portfolio, the market volatility of such financial assets could sometimes be too large in short term periods for those central banks that prefer not to be exposed to have negative returns.

Although a market risk limit allows to implement this framework without overlooking such concerns, there is a trade-off with the immunization provided. The lower the tolerance of a central bank to have volatility in its reserves portfolio, the lower the hedge provided to external shocks. Therefore, the higher the market risk limit, the higher the probability of constructing an efficient frontier that is not very different from the one derived from traditional optimizations. Nevertheless, as we'll show in the next section, even an optimization run under very strict limits is better than running an optimization without any consideration to the correlations between the financial assets' portfolio and external shocks.

## 4. Implementation in practice: traditional optimization vs hedging against shocks

When implementing a framework as the already described, there are several features that can be analyzed in order to understand the benefits of enhancing the traditional optimization analysis through the inclusion of external shocks.

In this section we present an implementation of this framework for emerging markets in Latin America (Latam). We use an "asset shock index" (ASI) where real terms-of-trade shocks and financial shocks for Latam countries are emulated through the change in the JPMorgan EMBI+ Latam Index and the change in an exports-weighted Latam index constructed with the Citi Terms-of-Trade Index for each country.

Although this ASI is slightly different than the synthetic asset we have defined for Argentina, this general example helps to present our main findings without being exposed to the idiosyncratic part of a country. In addition, in this section we use the Black-Litterman reverse optimization framework to show the results without being influenced by expected returns.

As a first step, we'll start analyzing the correlation between the ASI and different indices from the ICE BofAML Index universe to draw conclusions about the convenience to use this framework to incorporate certain features in the portfolio in terms of currencies, duration, credit ratings and asset classes. Then we show the changes in the optimal allocation that are driven by the inclusion of external shocks and how these changes are impacted when market-risk limits are introduced to control balance-sheet concerns.

### 4.1. Main features to consider when hedging against shocks

#### 4.1.1. Currency risk

The currency composition of central bank reserves have shown for the last thirty years a dominant role of the US dollar, representing more than 60% of central bank reserves[8].

Although there is no common framework among central banks to define the currency composition of a reserves portfolio, among most emerging markets we generally find that Latin and Central American

[8] See IMF, Currency Composition of Official Foreign Exchange Reserves (COFER)

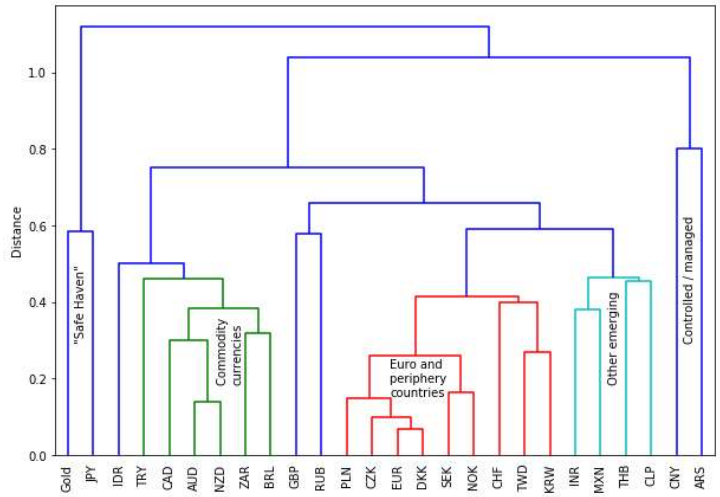
countries typically tend to invest mainly in US dollars, whereas central banks of economies highly integrated with the Eurozone tend to hold most of its reserves in euro-denominated assets[9].

This currency composition shows not only the dominant role of the main reserve currencies, but also how central banks structure their reserves portfolio. Lu and Wang (2019) show that most central banks usually follow a portfolio optimization strategy where they create a “liquidity tranche" portfolio and an “investment portfolio”. The “liquidity tranche” is designed to finance the day-to-day FX needs (which are mostly in US dollar for most emerging markets), and the “investment portfolio” pursues the highest return subject to risk constraints[10]. As a result, the larger the relative size of the liquidity tranche, the more important the effect of some balance of payments components to define the currency composition of the reserves’ portfolio. Conversely, the larger the relative size of the investment tranche, the larger the effect of reserve currencies' expected returns on the currency composition of FX reserves[11].

This probably helps to explain why the strong accumulation of reserves in recent years (i.e. the increase of the investment portfolios) lead to a widening in the landscape of the reserves’ currency composition to new alternative currencies such as the Aussie (AUD), the Canadian dollar (CAD), the Korean won (KRW), Scandies (NOK, SEK, DKK) and, more recently, the Renminbi (RMB); usually seen as vehicles to increase the “diversification” of the reserves’ portfolio.

Nevertheless, from a risk management perspective, it is more important to understand how “diversification” works in relation to a country’s own macroeconomic risk factors rather than diversifying the correlation among currency returns, as this can help central banks to mitigate some risk factors at a country level or, at least, to avoid doubling up[12].

***Figure 3. Currency Clusters and Underlying Risk Factors[13]***




Source: Bloomberg. Distance = 1 – correlation versus USD (period 2006-2018).

[9] Invesco (2019), p.5
[10] Lu and Wang (2019), p.4
[11] Lu and Wang (2019), p.35
[12] Invesco (2019), p.6
[13] Invesco (2019), p.7

In figure 3 we see a useful illustration shown by Invesco (2019) of currency groups that tend to move in tandem and with other factors such as region, commodities, or "flight to safety" during periods of heightened market volatility.

Not surprisingly, when we look into a group of indices corresponding to government debt with maturity from 1 to 10 years, we can clearly identify the risk factors that traditional optimizations may overlook when focusing only in the diversification of currency returns without considering the covariance with external shocks. In figure 4 we see that, as Latam countries tend to have a large exposure to commodity prices, government bond indices exposed to commodity currencies such as the Australian or Canadian dollar tend to show a strong and positive correlation to the ASI, meaning that if they were included in the investment portfolio they will only intensify the impact of external shocks in the reserves portfolio when reserves are more needed.

***Figure 4. Covariance/Correlation between the Asset Shock Index (ASI) and ICE BofAML Government Bond Indices*** [14]

**Covariance Matrix**

| Assets\Term | Currency | Unhedged | | | | 100% Hedged to USD | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1-3yr | 3-5yr | 5-7yr | 7-10yr | 1-3yr | 3-5yr | 5-7yr | 7-10yr |
| United States | USD | -0.06% | -0.13% | -0.16% | -0.20% | - | | | |
| Germany | EUR | 0.23% | 0.18% | 0.14% | 0.09% | -0.04% | -0.09% | -0.13% | -0.17% |
| France | EUR | 0.23% | 0.18% | 0.14% | 0.11% | -0.04% | -0.08% | -0.12% | -0.15% |
| Italy | EUR | 0.21% | 0.17% | 0.14% | 0.11% | -0.04% | -0.08% | -0.11% | -0.14% |
| Spain | EUR | 0.20% | 0.15% | 0.12% | 0.09% | -0.05% | -0.10% | -0.14% | -0.17% |
| Japan | JPY | 0.20% | 0.17% | 0.14% | 0.11% | 0.00% | -0.03% | -0.06% | -0.10% |
| United Kingdom | GBP | 0.29% | 0.24% | 0.19% | 0.16% | -0.05% | -0.10% | -0.15% | -0.18% |
| Canada | CAD | 0.67% | 0.63% | 0.62% | 0.60% | -0.03% | -0.06% | -0.08% | -0.10% |
| Australia | AUD | 0.85% | 0.76% | 0.71% | 0.67% | -0.08% | -0.16% | -0.22% | -0.26% |
| Sweden | SEK | 0.52% | 0.46% | 0.52% | 0.38% | -0.02% | -0.08% | -0.09% | -0.16% |
| Switzerland | CHF | 0.09% | 0.05% | 0.01% | -0.03% | -0.04% | -0.08% | -0.11% | -0.16% |
| India | INR | 0.31% | 0.28% | 0.28% | 0.22% | -0.02% | -0.06% | -0.06% | -0.12% |
| China | CNY | -0.11% | -0.15% | -0.15% | -0.19% | -0.04% | -0.08% | -0.09% | -0.13% |

**Correlation Matrix**

| Assets\Term | Currency | Unhedged | | | | 100% Hedged to USD | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1-3yr | 3-5yr | 5-7yr | 7-10yr | 1-3yr | 3-5yr | 5-7yr | 7-10yr |
| United States | USD | -0.42 | -0.40 | -0.38 | -0.38 | - | | | |
| Germany | EUR | 0.21 | 0.16 | 0.12 | 0.08 | -0.31 | -0.33 | -0.35 | -0.35 |
| France | EUR | 0.21 | 0.16 | 0.13 | 0.10 | -0.26 | -0.29 | -0.31 | -0.30 |
| Italy | EUR | 0.18 | 0.14 | 0.11 | 0.09 | -0.20 | -0.19 | -0.20 | -0.20 |
| Spain | EUR | 0.18 | 0.13 | 0.09 | 0.07 | -0.24 | -0.27 | -0.26 | -0.26 |
| Japan | JPY | 0.18 | 0.16 | 0.13 | 0.10 | -0.05 | -0.27 | -0.33 | -0.34 |
| United Kingdom | GBP | 0.32 | 0.27 | 0.21 | 0.17 | -0.30 | -0.34 | -0.37 | -0.34 |
| Canada | CAD | 0.76 | 0.72 | 0.69 | 0.65 | -0.23 | -0.28 | -0.26 | -0.23 |
| Australia | AUD | 0.63 | 0.58 | 0.55 | 0.51 | -0.51 | -0.54 | -0.51 | -0.46 |
| Sweden | SEK | 0.41 | 0.37 | 0.58 | 0.30 | -0.15 | -0.27 | -0.28 | -0.31 |
| Switzerland | CHF | 0.09 | 0.05 | 0.01 | -0.03 | -0.36 | -0.36 | -0.35 | -0.36 |
| India | INR | 0.47 | 0.38 | 0.34 | 0.25 | -0.10 | -0.17 | -0.14 | -0.21 |
| China | CNY | -0.31 | -0.37 | -0.35 | -0.35 | -0.25 | -0.28 | -0.24 | -0.25 |

However, it is also very interesting to note that when Australian or Canadian government bonds are fully hedged to the US dollar, they become negatively correlated to the ASI and, in some cases they can even show a more negative correlation than US Treasuries, as a sharp drop in commodity prices reduces growth prospects in commodity exposed countries, increasing the probability of having an easing in the monetary

[14] Covariance and correlation figures were estimated using monthly data from 1998 to September 2019.

policy, pushing yields lower and, therefore, causing an increase in the price of these government bonds. So, when looking to diversify external risk exposure, some currencies hedged to the US dollar could even work better than clean currency exposure.

The currency analysis covers just one dimension of the decision. The duration decision is another dimension in which the benefits of this analysis can also be valued.

#### 4.1.2. Duration risk

Under a traditional mean-variance optimization, the duration decision in fixed income portfolios mainly balances the trade-off between a higher expected return and a higher volatility of such expected return (i.e. a higher return-at-risk). Therefore, under the traditional approach, the volatility of financial assets causes a utility loss.

Central banks that are, in general, highly risk-averse investors and set up “safety” and “liquidity” as their primary goals to the investment of its reserves, when they construct their efficient frontier they often try to get the highest yield up to the point where they are confident that the risk of having negative returns during some time horizon (e.g. the fiscal year) is under control.

Only more recently and as a result of the accumulation of FX reserves and the growth of their “investment portfolios”, central banks started to be more focused in obtaining higher returns, increasing the duration of their portfolios as a way to achieve this goal.

Although the low yield and term premium scenario of recent years doesn’t seem to be adequately compensating for taking more duration risk, when hedge properties against external shocks are introduced in the optimization process, the benefits of having a higher duration clearly help central banks to find their compensation.

Indeed, in risk-off scenarios US Treasuries and other safe government bonds tend to rally. The longer the duration, the higher the gain, which occurs concurrently when reserves are more needed.

The covariance between the ASI and external shocks clearly shows this extremely important characteristic that is usually overlooked in traditional optimizations: the more efficient hedge per money invested. Similar results are observed in the covariance between the ASI and the indices of the largest government bond markets.

It is important to note that when the definition of risk is expanded to include the volatility caused by external shocks, a higher volatility in the financial assets may no longer represent an utility loss, as this higher volatility includes changes that are compensating the impact of negative shocks.

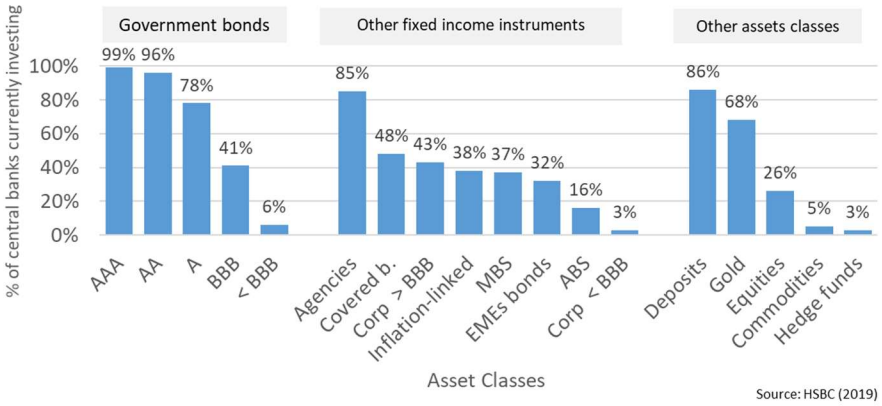
Therefore, the duration analysis under this framework shows that when central banks are increasing the duration of their portfolios, they are contributing to obtain a higher yield (when term-premium is positive) but also to better hedge its macroeconomic risks under risk-off scenarios.

4.1.3. Asset classes and credit risk

Reserve managers have always remained very committed to government bonds, the mainstay of reserve management[15].

Reserve managers have also usually added other asset classes to their portfolios: deposits and money market instruments in their "liquidity portfolio", and agencies, supras, mortgage-backed-securities, and corporates (i.e spread products) in their "investment portfolio".

***Figure 5. Asset allocation in central bank's reserves management***




HSBC (2019) shows that almost all central banks are currently investing in government bonds, and most of them also invest in agencies, deposits and gold. They also show that about 84% of central banks have recently added a new asset class to their reserves' portfolio, where the most popular asset added was corporate bonds, followed by emerging-market bonds, mortgage-backed securities, exchange-traded funds (ETFs), equities, and inflation-linked bonds[16].

When looking into asset classes, there are also a few major conclusions that can be drawn by considering the hedge properties against external shocks.

***Figure 6. Covariance/Correlation between the Asset Shock Index (ASI) and different asset classes***

| Correlation with ASI | | | | |
|---|---|---|---|---|
| **Asset class** | **1-3yr** | **3-5yr** | **5-7yr** | **7-10yr** |
| **US Treasuries** | -0.42 | -0.40 | -0.38 | -0.38 |
| **US Agency** | -0.34 | -0.29 | -0.26 | -0.22 |
| **US Corp AAA** | 0.00 | -0.02 | -0.01 | -0.01 |
| **US Corp AA** | 0.09 | 0.07 | 0.13 | 0.13 |
| **US Corp A** | 0.34 | 0.27 | 0.27 | 0.24 |
| **US Corp BBB** | 0.40 | 0.37 | 0.41 | 0.40 |
| **US Supras AAA** | -0.19 | -0.10 | 0.00 | 0.05 |
| **US MBS** | -0.03 | -0.10 | -0.07 | -0.39 |
| **US TIPS** | 0.61 | 0.46 | 0.35 | 0.28 |

| Covariance with ASI | | | | |
|---|---|---|---|---|
| **Asset class** | **1-3yr** | **3-5yr** | **5-7yr** | **7-10yr** |
| **US Treasuries** | -0.06% | -0.13% | -0.16% | -0.20% |
| **US Agency** | -0.05% | -0.08% | -0.10% | -0.11% |
| **US Corp AAA** | 0.00% | -0.01% | 0.00% | 0.00% |
| **US Corp AA** | 0.02% | 0.03% | 0.07% | 0.09% |
| **US Corp A** | 0.11% | 0.13% | 0.18% | 0.18% |
| **US Corp BBB** | 0.16% | 0.21% | 0.31% | 0.34% |
| **US Supras AAA** | -0.03% | -0.03% | 0.00% | 0.03% |
| **US MBS** | -0.01% | -0.02% | -0.02% | -0.13% |
| **US TIPS** | 0.14% | 0.16% | 0.16% | 0.17% |

[15] HSBC (2019), p.40
[16] HSBC (2019), p.39 and 41

First, we can see in figure 6 that US Inflation-linked bonds (US TIPS), which have been regarded as good diversifiers for any reserves' portfolio, are even more correlated with the ASI than US Corporate bonds, meaning they would only augment the procyclicality of the reserves' portfolio for Latam countries. The rationale behind this is very simple: the change in the price of commodity prices usually goes hand in hand with the change in the US inflation and, therefore, the relative performance of US TIPS.

Second, for assets with similar duration, US Treasuries are the most risk diversifier asset class of external shocks, above US Corporates, US Agencies, US Supras and other spread products. This is consistent with the procyclicality usually observed in credit spreads, meaning that adding too many spread products will also add procyclicality to the reserves' portfolio, which does not help to construct the countercyclical type of portfolio that should be constructed to enhance the management of macroeconomic risks.

Third, credit ratings are also impacting the procyclicality of the reserves' portfolio. In figure 6 we can see that the lower the rating, the higher the covariance with the ASI. This is consistent with the fact that risk-off scenarios and financial shocks usually affect the funding of low rated companies. Therefore, if reserve managers were investing reserves in low rated companies, they would be adding a share in the funding risk of such low rated companies, which are challenged in risk-off scenarios, augmenting the risk of their reserves' portfolio when reserves are more needed.

### 4.2. Implementation results for Latam countries

All the features presented in the previous section are examples of how portfolios that may be optimal for traditional asset-only investors, may be sub-optimal when the definition of risk is expanded to include the volatility in the reserves' portfolio caused by external shocks.

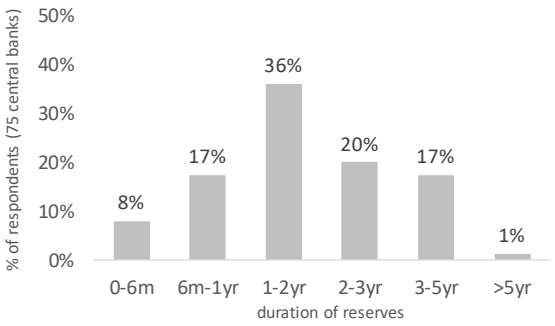
Under traditional mean-variance optimizations, the efficient frontier is constructed through selecting the lowest balance sheet reserves' volatility per unit of expected return. When the definition of risk is expanded to include the volatility in the reserves' portfolio caused by external shocks, we introduce the possibility to use financial assets for two different purposes: to hedge the financial risk stemming from another financial asset but also to act as a hedge against those macroeconomic risks and vulnerabilities of the national balance sheet.

The inclusion of the hedge decision in the strategic asset allocation can drastically change the optimal composition of the efficient frontier.

The most important change is found in the duration risk dimension. Under traditional optimizations of fixed income portfolios, the minimum variance portfolio and other portfolios of low volatility are predominantly composed by short duration strategies, which is fully consistent with the average duration we usually find in the reserves' portfolios of central banks, where short duration strategies predominate over long duration ones.

For high-risk averse investors as central banks it's generally very difficult to find significant exposures to long duration strategies. In figure 7, for example, we can see that more than 80% of central banks are currently investing in portfolios with an average duration under 3 years.

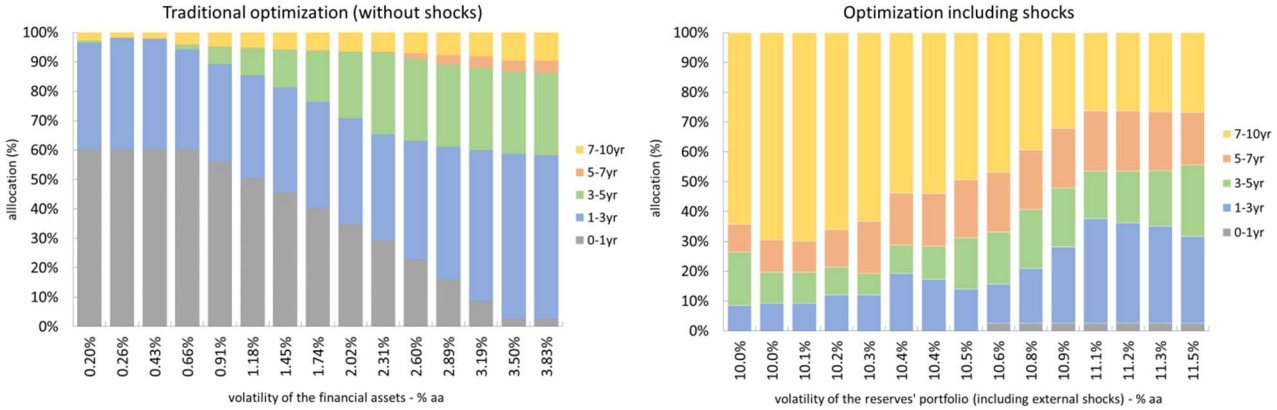
***Figure 7. Duration of the Reserves' portfolio***




*Source: HSBC (2019)*

But when the risk dimension is expanded to include the risk of external shocks, there is an important shift in the optimal duration of the reserves' portfolio. Long duration strategies start to play a key role to hedge external shocks and the optimal composition for the efficient frontier is predominantly composed by them, as we can see in figure 8. The longer the duration, the better the hedge provided.

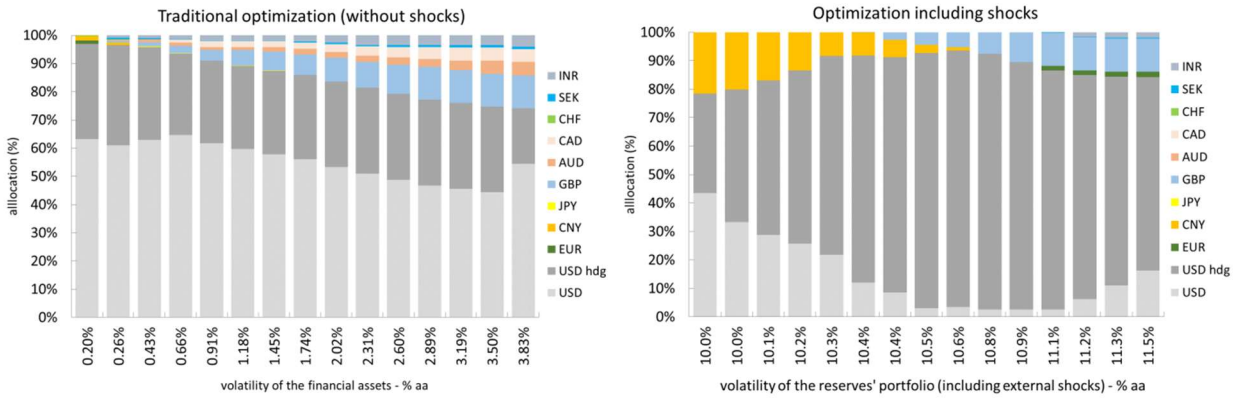
***Figure 8. Efficient portfolios per duration bucket***




It's also interesting to note that, under the expanded risk dimension, the minimum-variance portfolio holds a higher allocation in long duration strategies than other efficient portfolios that are showing a higher volatility for the reserves' portfolio. This is usually inconsistent with the efficiency concept under the traditional approach, as a higher allocation in long duration strategies generally causes a higher volatility for the financial assets' portfolio. However, when the risk dimension is expanded to include the risk of external shocks, the hedge properties of long duration strategies predominate in the asset allocation decision: the lower the allocation to these assets, the lower the hedge to external shocks, and the higher the volatility of the reserves' portfolio.

For the currency composition of a reserves' portfolio, we can see in figure 9 that the inclusion of external shocks does have an impact, but mainly in the distribution between US dollar-denominated assets and other assets fully hedged to the US dollar.

***Figure 9. Efficient portfolios per currency bucket***

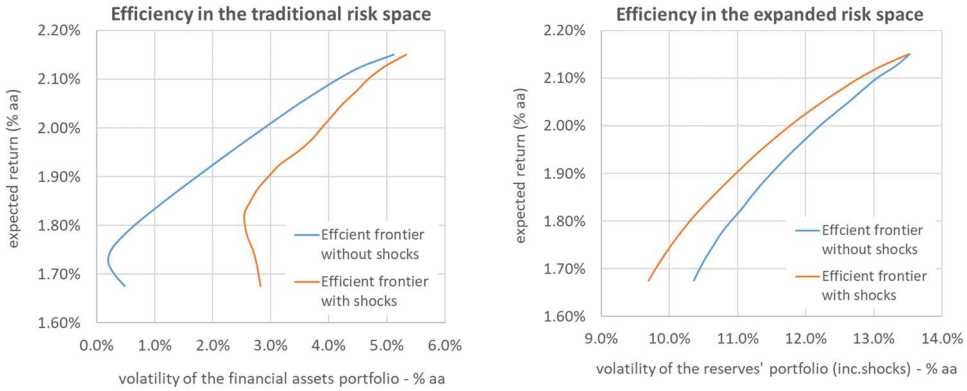



In figure 9 we can also see that the exposure to AUD and CAD suggested by a traditional currency returns´ diversification approach, goes to zero when shocks are included in the risk dimension (i.e. when the underlying risk factors start to influence the asset allocation decision).

The different allocations proposed in the two different risk dimensions clearly show that the frontier that is efficient to hedge external shocks may not be efficient in the traditional landscape where the hedge properties are overlooked and risk is only defined as the volatility of the financial assets portfolio.

Conversely, when the risk dimension is expanded to include the risk stemming from external shocks, the frontier that is efficient in the traditional landscape, may no longer be efficient in the expanded risk dimension.

***Figure 10. Efficient frontiers in the different risk dimensions***




Although there is a trade-off in the efficiency decision between the two different risk dimensions for low-volatility portfolios, we can see in figure 10 that efficient allocations in both risk dimensions tend to converge when we move to those financial assets portfolios with the highest volatility, as the investment universe for such higher expected returns tend also to decrease.

4.3. Implementation results with market-risk limits[17]

Central banks have always tried to avoid any reputational concern. Indeed, most central banks have been very reluctant to shift their reserves portfolio to long duration strategies that have a higher yield, but also a higher return-at-risk and may expose the central bank to have negative returns.

In order to deal with those reputational concerns arising from long duration strategies, some central banks use "Hold-to-Maturity" portfolios, other central banks try to enhance their communication strategy, while other central banks simply prefer not to be exposed to such financial risks.

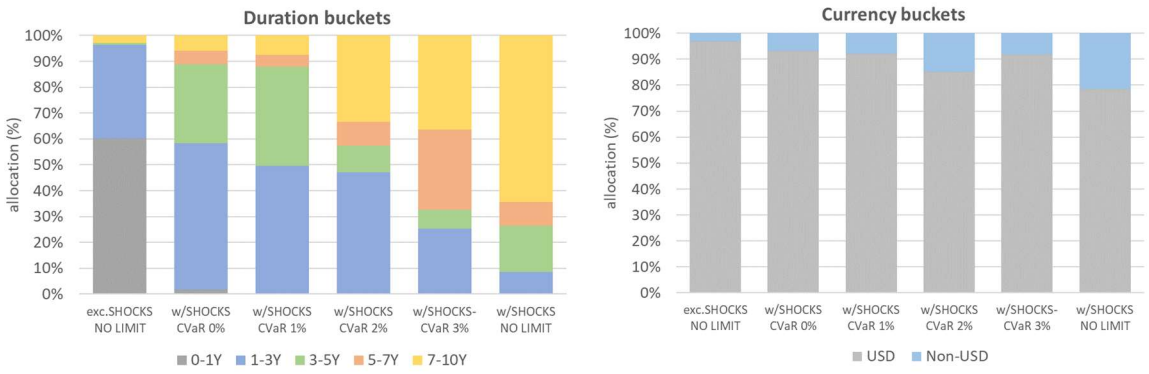
The use of market-risk limits in the strategic asset allocation process is also a common practice that is used to control the financial assets' portfolio volatility and, therefore, reputational concerns.

Although the use of market risk limits shifts the optimal asset allocation to a suboptimal one, it's certainly better to use these limits and enhance the risk management framework, rather than not considering the immunization provided to external shocks at all.

When we include market-risks limits in the expanded risk dimension, the higher the limits, the lower the hedge provided to macroeconomic risks and the more similar the efficient allocation is to the one proposed in the traditional mean-variance framework.

In figure 11 we can see in the implementation we run for Latam countries how the optimal allocation to short-duration strategies would change for the minimum-variance portfolio with different market-risk limits. In the traditional no-shocks approach (on the left), the efficient frontier would suggest a 96% allocation to 0-3yr duration strategies. Conversely, if shocks were included without market-risk limits (on the right), the efficient frontier would suggest only a 9% allocation to 0-3yr duration strategies. Between the two, there are different allocations suggested depending on the market-risk limit. For example, if shocks were included using a Conditional Value-at-Risk (CVaR) that is limited to 3%, the optimal allocation to 0-3yr duration strategies would increase to 25%. If the CVaR were limited to 1%, the optimal allocation would shift to 50%.

***Figure 11. Optimal allocation with different market-risk limits for minimum-variance portfolios***




For the optimal currency composition we can see in figure 11 that the traditional no-shocks approach would recommend a 97% exposure to the US dollar for those minimum variance portfolios that use the

[17] We use "market-risk limits" to define those limits placed in the volatility of the financial assets´portfolio.

US dollar as numeraire. The exposure suggested to the US dollar moves down to 78% if shocks are included without market-risk limits. If shocks were included using a CVaR limit of 1%, the optimal allocation to the US dollar would shift to 90%.

Therefore, even if the introduction of market-risk limits shifts the optimal composition to a suboptimal one, where the hedge to macroeconomic risks is reduced, there are significant changes that could be introduced to enhance the risk management of the national balance sheet, especially in the duration dimension, if shocks are considered for the strategic asset allocation.

## 5. Final remarks

The introduction of external shocks in the strategic asset allocation framework leads us to draw some interesting conclusions.

First, there is value to include this kind of analysis for central banks, as it's a way to better understand the underlying risk factors of the national balance sheet, preventing to double up the main vulnerabilities of each country but also to have procyclicality behaviors that would only exacerbate the challenges faced in risk-off scenarios (i.e. when reserves are more needed).

Prudent economies are generally forced to incur in a variety of costly precautionary measures in order to mitigate the risk of being impacted by a sudden-stop scenario. As discretionary portfolio decisions do affect the national risk profile, prudent economies should also try to enhance the risk management of their national balance sheet.

Even if reserves' portfolios are tranched into two or more separate portfolios, the long-term "investment portfolios" are always working as a supplemental buffer to the other short-term "liquidity portfolios". Therefore, the covariance between the financial assets' portfolio and those shocks that may trigger the probability of transfer funds from the long-term portfolio to the short-term one shall not be overlooked in the asset allocation decision. Between two financial assets with the same expected return and volatility, the optimizer should choose the asset having the lowest correlation with the main vulnerabilities of the country.

In this sense, there are always "right-way risks" that central banks can take when considering to increase the expected returns of their reserves' portfolio. A higher duration risk, for example, goes in the right direction and the inclusion of the volatility caused by external shocks in the reserves' volatility risk dimension is key to help central banks to find their compensation for taking a higher duration risk, especially in the current low yield and term-premium scenario.

The traditional optimization approach generally overlooks the underlying risk factors. There is no difference between advanced and emerging market countries for the strategic asset allocation framework when the efficient frontier is constructed from an "asset-only" risk-return perspective. Same allocations are recommended to very different countries, with very different risk profiles and exposures in their national balance sheet. As there are currency clusters, there are many other risk factors that are relevant, especially for those countries more vulnerable to external shocks. These factors should play a role in the strategic asset allocation of the reserves' portfolio.

Central banks are key players to safeguard financial stability. They should always try to construct portfolios that are countercyclical or, at least, that are not exposed to have procyclical behaviors that could exacerbate market volatility. The traditional optimization approach does not help to prevent procyclicality behaviors. The expanded risk dimension does.

The solution we propose is just an on-going work that tries to go in the right direction. There is no framework that gives to any central bank and/or investor the masterpiece to find the best portfolio for all kind of scenarios. Portfolios that perform well in some scenarios, will certainly perform bad in other scenarios. The hedge decision has, indeed, the intrinsic unwelcomed result that when there is a positive shock for the national balance sheet (e.g. an increase in commodity prices for EMEs), there will be a countercyclical impact in the reserves' portfolio, causing a poor performance or even a negative return.

However, under such scenarios is when reserves are less needed and the marginal utility of an extra unit of reserves decreases. The only challenge to central banks is how they manage market expectations and the reputational risks that may arise when having a poor performance in the reserves' portfolio.

One way to manage these concerns is through the introduction of market-risk limits in the optimization process. As we showed, even an implementation with market risk limits is better than having a framework with no shocks at all. Although the higher these limits, the more similar will be the optimization to a traditional one, there is still a lot of information provided by this framework that is useful to avoid doubling-up risks.

Another way to manage these concerns is through a strong and clear communication policy. This is probably the best way to go, as the hedge provided to macroeconomic risks will not be a sub-optimal one, but is certainly the most challenging one, especially for those countries that have a closer scrutiny to changes in their reserves' portfolio.

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