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Foreign exchange reserves, imperfect substitutability of financial assets and the monetary policy quadrilemma

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Foreign exchange reserves, imperfect substitutability of financial assets and the monetary policy quadrilemma

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In this paper, I investigate how the use of foreign exchange reserves can turn the monetary policy trilemma into a quadrilemma. After surveying recent developments in international macroeconomics literature, including the dilemma vs trilemma debate and the dominant currency paradigm, I make a twofold contribution to support the case for the quadrilemma. The first contribution is a logical characterisation of the quadrilemma in the form of a single equation which includes exchange rate variations, interest rate differential, capital controls and the level of reserves. The second contribution consists of a nominal stock-flow consistent model with two countries, characterised by perfect capital mobility and imperfect asset substitutability, to study the pure effect of international investors' portfolio reallocation following unanticipated changes in the policy rate of the domestic economy. The model is run several times, varying the direction of the monetary policy shock and the relative size of the two countries. Two constraints on reserves are highlighted, one in the short run and one in the long run – albeit less significant – which define the limit between the classical trilemma and the quadrilemma.

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I. Introduction

The tremendous accumulation of official foreign exchange reserves (hereafter 'FX reserves') over the last decades is one of the most striking features of the international economy. An increase in the ratio of international reserves to GDP (cf. Figure 1) has been observed mostly in emerging markets across Asia and Latin America, as well as certain advanced economies such as Japan and Switzerland. This follows a change in the perceived role and use of international reserves held by central banks, which has gone from mainly passive and residual to active and strategic. It is now accepted that "foreign exchange intervention in the spot market can counter a sharp depreciation of overshooting of [a country's] currency" (People's Bank of China 2019) and that FX reserves provide "insurance against external turbulence" (Central Bank of Brazil 2019).

Research on the topic was initially driven by the work of practitioners – economists working in central banks, think tanks or international organisations – and more recently translated into macroeconomic theory. A new consensus is emerging, whereby using reserves as a policy tool can improve monetary policy autonomy in a flexible exchange rate regime or help maintain a fixed peg (Basu & al. 2020, Bianchi & Lorenzoni 2021). This newly found policy role for international reserves has deep consequences for the conduct of monetary policy in an open setting. By adding reserves to the list of policy tools, one can turn the famous monetary policy trilemma into a quadrilemma – as has been emphasised implicitly by Frenkel (2007) and explicitly by Aizenman (2013, 2019).

This paper offers a twofold contribution to support the case for the quadrilemma. The first contribution is a logical characterisation of the quadrilemma in the form of a single equation which includes exchange rate variations, interest rate differential, capital controls and the level of reserves. The second contribution consists of a nominal stock-flow consistent model with two countries, characterised by perfect capital mobility and imperfect asset substitutability, to study the pure effect of international investors' portfolio reallocation following unanticipated changes in the policy rate of the domestic economy. The model is run several times, varying the direction of the monetary policy shock and the relative size of the two countries. Two constraints on reserves are highlighted, one in the short run and one in the long run – albeit less significant – which define the limit between the classical trilemma and the quadrilemma.

The rest of this paper is organised as follows. The next section provides a non-exhaustive survey of the literature on the rise of FX reserves in the recent decades. Section 3 reviews the monetary policy trilemma and highlights some of its shortcomings. Section 4 discusses recent developments in international economics, namely the quadrilemma versus dilemma controversy, as well as the

implications of the use of dominant currencies in pricing and financing processes. Section 5 presents the monetary policy quadrilemma in the form of a single equation. Section 6 contains a modelling attempt to display the most unorthodox application of the quadrilemma, that is the trilemma 'breach'. The model highlights the existence of asymmetric constraints on FX reserves in the short run, as well as a long-term inversion of FX reserve variations when flows are solely driven by investors' portfolio reallocation.

FX reserves to GDP in selected countries

Country	2020	2000	Change
Switzerland	144%	19%	(+125%)
China, P.R.: Hong Kong	142%	63%	(+79%)
Singapore	107%	83%	(+23%)
Czech Rep.	68%	21%	(+46%)
Thailand	51%	26%	(+26%)
Israel	43%	18%	(+25%)
Peru	36%	17%	(+19%)
Malaysia	32%	28%	(+4%)
Iceland	30%	4%	(+25%)
Japan	28%	7%	(+20%)
Korea, Rep. of	27%	23%	(+5%)
Hungary	27%	24%	(+3%)
Poland, Rep. of	26%	16%	(+10%)
Brazil	25%	5%	(+20%)
China, P.R.: Mainland	23%	14%	(+9%)
India	22%	22%	(0%)
Colombia	22%	9%	(+12%)
Norway	21%	16%	(+4%)
Denmark	20%	9%	(+11%)
Mexico	19%	5%	(+14%)
South Africa	16%	7%	(+9%)
Chile	16%	19%	(-3%)
Turkey	13%	9%	(+4%)
Indonesia	13%	11%	(+2%)
Sweden	11%	7%	(+4%)
Argentina	10%	8%	(+2%)
United Kingdom	8%	3%	(+5%)
New Zealand	7%	7%	(-1%)
Canada	6%	4%	(+1%)
Australia	3%	5%	(-2%)
United States	1%	1%	(+0%)

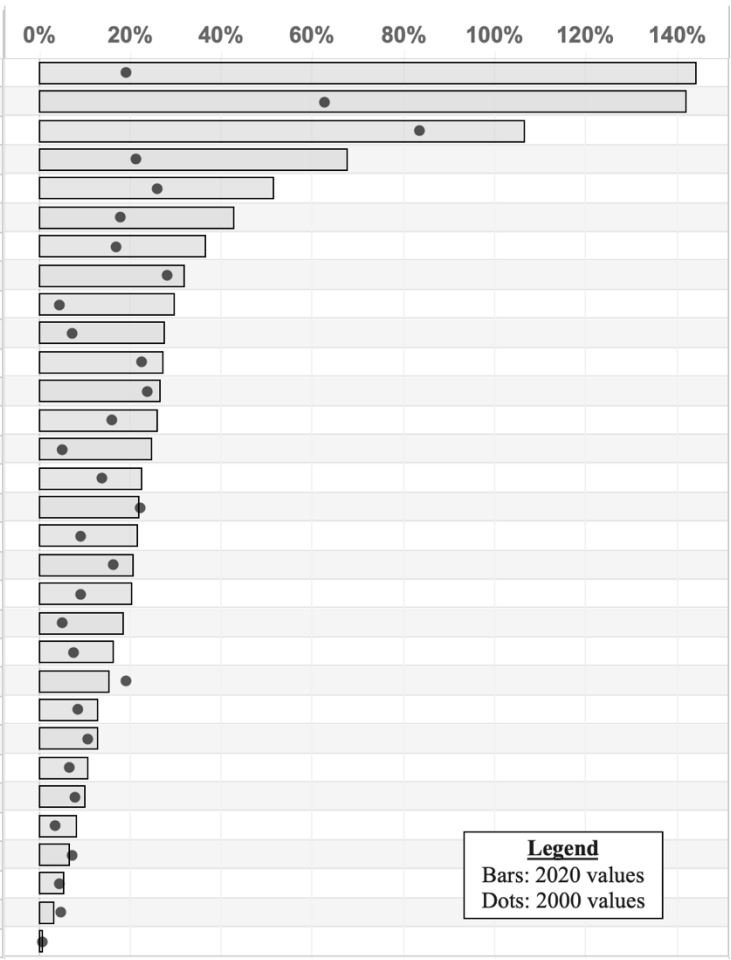

Table 1: FX reserves to GDP in selected countries (source: IMF)

II. The rise of FX reserves as a policy tool

The question of FX reserves has been around for centuries, if not longer. In the context of metallic standard systems, countries with insufficient reserves were expected to devalue their currency against gold to restore their trade balance or increase interest rates to attract capitals. During the Bretton Woods era, insufficient reserves would provoke "balance-of-payment crises" which later became "currency crises" (Krugman 1979, Obstfeld 1984). However, in neither of these contexts were reserves given an active role to play in terms of policy making, they were merely regarded as a residual determined passively by trade, income and capital flows.

An evolution occurred at the end of the 1990s and early 2000s, whereby reserves acquired a more active and strategic role (Aizenman 2019). This paradigm shift followed a decade of violent currency crises in Asia and Latin America: Mexico in 1994-1995, Thailand, Indonesia and South Korea in 1997-1998, Brazil in 1999, Argentina in 2001. Calvo & Reinhart (2002) talk about "fear of floating" to describe the behaviour of emerging countries whose currencies officially float freely but who effectively intervene on foreign exchange markets to limit exchange rate fluctuations. Using daily data from Mexico and Turkey, Domaç & Mendoza (2004) show that foreign exchange interventions can indeed reduce short-term exchange rate volatility, which can prove pivotal in achieving inflation targeting in countries where the pass-through from exchange rate to inflation is high.

Aizenman & Lee (2007) provide an early discussion of the potential reasons behind the accumulation of FX reserves, which they call "motives". The first one is the precautionary motive, which corresponds to a self-insurance usage of reserves to avoid financial disruption linked with current account deterioration, sudden stops of capital inflows or speculative attacks. Then comes the mercantilist motive, whereby reserve accumulation aims to neutralise appreciating forces in the foreign exchange market, often as part of a broader strategy of export-base growth. Using a sample of 58 countries, advanced as well as emerging, the authors conclude to an overall greater relevance of the precautionary motive. Notably, they find the degree of capital account liberalisation to be statistically significant and positively correlated with the ratio of international reserves to GDP across the sample. This implies that "capital market developments are a robust factor behind the recent build-up in international reserves, if not the single most important factor" (p.200).

According to Arslan & Cantú (2019), the precautionary motive was progressively superseded by goals associated with monetary and exchange rate policies. Aizenman & al (2015) investigate the changing nature of the hoarding of international reserves in the aftermath of the Great Financial Crisis using principal component analysis on data consisting of 95 countries – of which 22 advanced – from

1999 to 2012. Their results highlight changes in the determinants underpinning reserve accumulation after the financial crisis. The volatility in commodity prices that characterised the late 2000s led many countries, in particular emerging ones, to use their reserves to cushion these shocks, which constitutes another declination of the precautionary motive. Aizenman & al (2015) also point to the existence of significant differences in average hoarding between regions, measured by regional fixed effects, which they attribute to implicit rivalry between countries of the same region. The authors use as a potential explanation the existence of a "keeping up with the Joneses" effect first identified by Machlup (1966) and adapted to reserve accumulation by Cheung & Qian (2009).

Drawing on a survey of 21 central banks, Patel & Cavallino (2019) identify multiple operational objectives of foreign exchange intervention: influencing the level of the exchange rate, smoothing its trend path, limiting its volatility, limiting the pressure caused by international investors, and providing liquidity when the market is too thin. The end goals associated with these operational objectives include smoothing commodity prices, maintaining external competitiveness, as well as reducing foreign exchange speculation and funding shortages. As far as the implementation of FX intervention is concerned, spot market interventions remain the most common form although the use of forwards and derivatives has been on the rise – Brazil being an extreme case, where all FX intervention has been taking place in the form of FX swaps since 2013 (Central Bank of Brazil 2019). According to Patel & Cavallino, the main reason to use derivatives is to economise reserves and keep them for specific uses such as funding gaps. This confirms earlier results by Aizenman & al (2015) which found a negative correlation between international reserve accumulation and access to swap lines after the Great Financial Crisis.

In parallel with the benefits stated above, accumulating FX reserves also comes at a cost. Dutt (2021) lists three forms of concerns. The first one is the financial cost of hoarding reserves, since reserves can be invested in assets whose return is lower than the cost of central bank liabilities or could be invested in higher yielding assets. However, this cost must be compared with the gains coming from reduced financial instability and the associated lower risk premium. The second concern stems from the possibility of moral hazard since reserves can create a false feeling of safety and foster excessive risk-taking in the domestic economy. The third concern is of a more political nature: in the absence of a designated supranational institution acting as an international lender of last resort, there is a risk that access to FX refinancing facilities such as swap lines be given on a somewhat arbitrary basis or in a way interfering with the sovereignty of peripheric countries. It is therefore not possible to isolate a 'pure cost' of holding international reserves, since costs and benefits are intertwined. Within the scope of the present paper, I will assume that the accumulation of FX reserves over the course of several decades indicates that overall, the benefits of this accumulation outweigh its cost(s).

III. Cracks in the trilemma

The dominant approach to monetary policy theory in an open setting relies on the famous trilemma coming from Mundell (1963) and Fleming (1962). In its classical form, the trilemma or impossible trinity states that a country (or any geographical entity) cannot pursue an independent monetary policy while maintaining a fixed exchange rate in a context of freely moving capitals. Another way of stating the trilemma is to offer a choice between three configurations:

- 'Floating autonomy' characterised by flexible exchange rates, high capital mobility and autonomous monetary policy – the USA, Japan, India, Norway, Sweden, and the Euro area taken as a whole belong to this category.
- 'Monetary alignment' characterised by fixed exchange rates, high capital mobility and constrained monetary policy – member countries of the Euro area fall within this category, as well as countries pegged to external currencies such as Singapore or Denmark.
- 'Financial autarky' characterised by fixed exchange rate, low or non-existent capital mobility, and autonomous monetary policy – this configuration was encountered during the Bretton Woods era from 1944 to 1971, and more recently in China during most of the 1990s and 2000s.

An obvious caveat of the classical formulation of the trilemma is the reference to "monetary policy" as if it were an unambiguous term, whereas in both theory and reality, monetary policy is vastly heterogenous. As far as macroeconomic theory is concerned, monetary policy used to refer to changes in the quantity of money and has come to signify changes in interest rates only a few decades ago. Yet, not all countries use interest rates in the same way: some central banks use corridor systems consisting of multiple rates (e.g. the ECB) while others mostly rely on a single rate approach (e.g. the Bank of England or the National Bank of Switzerland). Certain central banks, such as the Monetary Authority of Singapore, do not even use interest rates as an official policy tool. Instead of talking about "monetary policy", it would therefore be preferrable to refer to precise policy measures, such as interest rate targeting or foreign exchange intervention.

The internal articulation of monetary policy frameworks also varies greatly across countries. For instance, Denmark uses interest rates as a tool to maintain a fixed exchange rate vis-à-vis the euro which is itself a way of importing price stability (Danish Nationalbank 2021a). By comparison, Singapore uses foreign exchange intervention as a way of keeping the nominal effective exchange rate within a crawling band, as exchange rate targeting is seen as a better way of stabilising prices than interest rate policy (Monetary Authority of Singapore 2021).

Notwithstanding this semantic caveat, the trilemma is still widely accepted as the most relevant way of framing challenges posed to monetary policy makers in an open economy (Obstfeld 2015, Obstfeld & al. 2017) although the way it is used has evolved over time. Notably, its interpretation has become more nuanced. For instance, the choice of exchange rate regimes has gone from a choice between two extremes, hard peg and pure floating, to considering intermediate arrangements, such as managed floating, crawling bands and pegs[2]. The mobility of capital can be measured using the Chinn-Ito index (Chinn & Ito 2006), which goes from zero to one. Monetary policy autonomy can be assessed by regressing interest changes in a given country on changes in interest rates in the core countries (Aizenman, Chinn & Ito 2013).

Lavoie (2014) introduces a distinction between capital mobility and asset substitutability. Capital mobility is related to technical and political factors, such as the development of financial markets, their degree of connection with abroad, and the absence of capital controls. Asset substitutability pertains to investors' preferences, as reflected in their portfolio allocation and reaction to price and yield changes. Lavoie insists that perfect capital mobility does not mean that yields will necessarily align, since investors treat various assets as imperfect substitutes.

It is possible to express imperfect asset substitution using a general interest-parity relationship:

$$\mathrm{r_{DOM}} = \mathrm{r_{FOR}} - \Delta \mathrm{xr^{e}_{DOM}} + \rho \qquad (3.1)$$

Where $r_{DOM}$is the domestic interest rate, r_{FOR} the foreign interest rate, Δxr^{e}_{DOM} the expected change in the domestic exchange rate xr (expressed as the number of foreign currency units per domestic currency units), and ρ a variable capturing the effects of imperfect asset substitution.

To understand the kind of pattern followed in the real world by the variable ρ from equation [1], the best option is to look at interest rate differentials between two financially integrated countries sharing similar economic fundamentals and linked with a fixed exchange rate. The case of Denmark, which has been conducting a fixed exchange rate policy since 1982, initially against the Deutsche Mark then against the euro[3], seems very relevant in that respect.

[2] This "bipolar" view of exchange rate regime choice (Fischer 2001) could explain at least partly why reserves have not been given a more prominent role in international monetary policy theory: under pure floating exchange rate regimes, reserves are supposed to remain constant as exchange rate determination is left to the market, while in hard peg contexts, the discretionary use of reserves is deemed impossible regardless of the degree of international capital mobility. As a results, reserves have no real role to play one way or the other.

[3] Although the official fluctuation band associated with the Exchange Rate Mechanism II (ERM 2) is ±2.25%, in practice over the last decade the National Bank of Denmark has effectively enforced fluctuation bands in the vicinity of ±0.35%.

Denmark is widely considered a very robust economy. Its current account surplus amounts to 7.5% of GDP on average since 2013, which is on par with Germany. Its public debt is highly rated by all agencies and stood at respectively at 33.3.% and 42.2% of GDP at the end of 2019 and 2020, while Germany public debt stood at 59.7% and 69.8%. Furthermore, Denmark is completely financially integrated with its European neighbours due to its belonging to the European Union, and it has demonstrated several times its ability to maintain a peg with Germany then the Eurozone.

Figure 1 shows the spread on the 10-year bond yields between Denmark and Germany from January 2006 to November 2021. A positive value indicates that the Danish yield was higher than the German yield. The average spread over the period is 0.139%, which means investors received on average this additional yield as a premium for holding Danish 10-year Government bonds. This fact is quite hard to reconcile with the traditional uncovered interest rate parity, even in its augmented version including a risk premium (Obstfeld 2015) since Denmark is, if anything, even more robust than Germany from an economic and financial perspective.

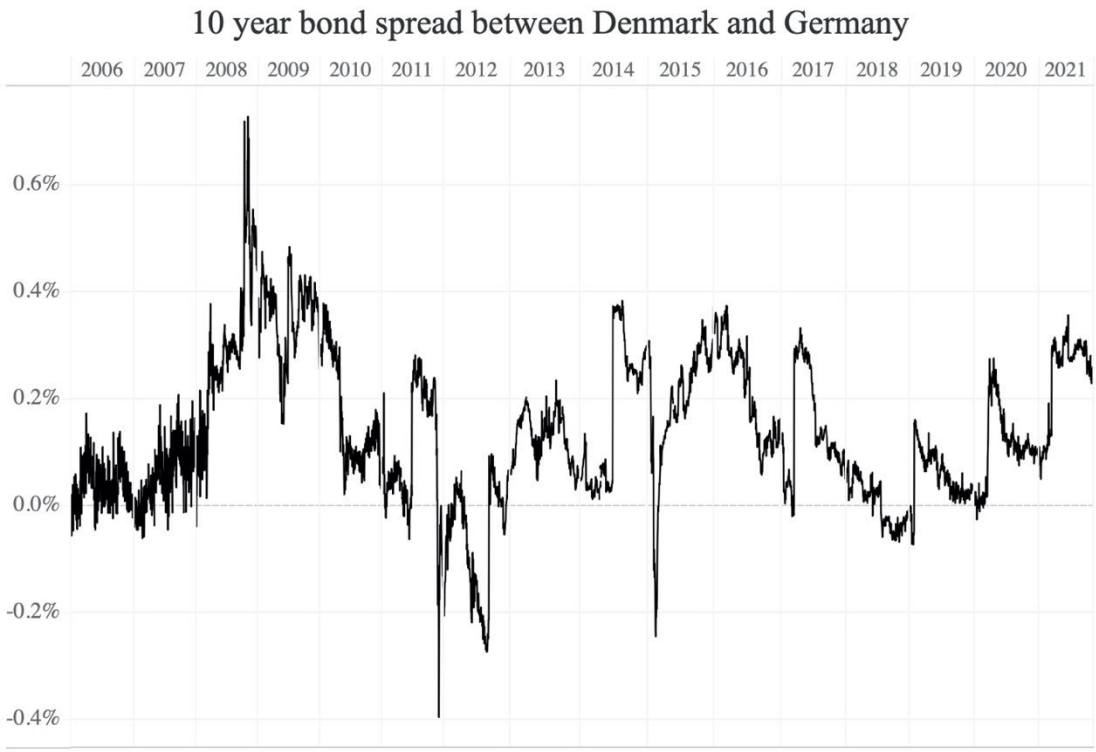

Figure 1: 10 year bond spread Denmark-Germany (source: investing.com)

Another striking feature of the spread over the period is its volatility. Although the spread has been positive most of the time, it ventured a few times under zero, reaching as low as -0.4% on 1 December 2011, -0.28% on 27 August 2012 and 0.25% on 12 February 2015 – at the height of a speculative

episode which triggered a rare and significant use of reserves by the Danish National Bank. When in positive territory, the spread went many times above 0.2% and stayed there for around a year in 2015-2016.

From these observations, it follows that the variable ρ for Denmark is slightly positive on average and oscillates between -0.1% and 0.4% most of the time. This seems hard to reconcile with the uncovered interest parity approach underpinning the classical trilemma.

IV. Beyond the trilemma: quadrilemma or dilemma?

Several authors have questioned the relevance of the trilemma for the globally financialised world of the early 21st century. Interestingly, the two main suggestions to revise the trilemma are going in apparently opposite directions (Dovonou 2021) since one camp argues the post-Bretton Woods era is characterised by the presence of financial stability which turns the trilemma into a quadrilemma (Aizenman 2013) while the other claims that the existence of a global financial cycle renders exchange regimes ineffective to hinder the transmission of monetary policy from centre to periphery, thus turning the trilemma into a dilemma (Rey 2013).

The quadrilemma approach

According to Aizenman (2013, 2019), the trilemma originated in the context of the Bretton Woods system, characterised by limited international capital mobility, fixed exchange rate regimes and autonomous national monetary policies, while since the end of Bretton Woods in 1971, former member countries have opened their financial account and most of them have opted for flexible exchange rate regimes. Both these factors have proved to be quite destabilising.

In the case of floating currencies, uncertainty created by violent fluctuations in the exchange rate have incentivised central banks to use foreign exchange intervention to smooth the exchange rate path and reduce its volatility, thus moving from free to managed floating. In the case of countries with pegged currencies – whether fixed or crawling – the accumulation of foreign reserves has contributed to the maintenance of the peg, China in the 1990s and 2000s being a prime example.

Unlike the Bretton Woods era, which saw no major financial crisis, the post Bretton Woods era has been ridden with financial instability, which was made possible by the high degree of financial integration between countries facilitating the circulation of 'hot money' flows, sudden stops and international credit spillovers. According to Aizenman, "concerns about financial stability morphed the trilemma into a quadrilemma" (Aizenman 2019, p.449). Although Aizenman identifies financial stability as the fourth corner of the trilemma, alongside exchange rate stability, financial integration and autonomous policy, in practice he uses foreign reserves as a measurable proxy.

Andaiyani & al. (2020) provide an application of the quadrilemma to Indonesia, using data covering the years 1983 to 2017 which they further break down into the two sub-periods before and after 1999. The authors find that FX reserves have significantly contributed to the overall macroeconomic adjustment process following monetary policy changes, but they argue that reserves could have played a greater role.

The fundamental insights of the quadrilemma – although not the term 'quadrilemma' itself – can be found earlier in Roberto Frenkel (2007) who states:

> In a context of free capital mobility, [… t]he condition for combining control of the exchange rate with the preservation of monetary autonomy is the existence of an excess supply of international currency at the exchange rate targeted by the central bank. That is, the conditions in the current account and capital account are such that the local currency would appreciate if the bank did not intervene to hold down the exchange rate. In this context, *the monetary authority can set the exchange rate by purchasing the excess supply in the currency market* and can control the interest rate by sterilizing the monetary effects of this intervention, which it does by issuing treasury or central bank bonds in the money market. The central bank has two instruments for achieving its two goals: *intervention in the foreign currency market to set the exchange rate* and intervention in the money market to determine the interest rate. (Frenkel 2007: 30, italics mine)

Frenkel goes on to suggest that in a context of international reserve scarcity, an asymmetry appears between surplus and deficit countries – the former being able to escape the trilemma due to their ability to regain reserves, while the latter cannot[4].

Even the most ardent proponents of the trilemma have admitted that the use of international reserves could have implications on the conduct of monetary policy in an open setting. For instance, Obstfeld (2015) notes that the accumulation of large stocks of FX reserves has acted as a stabilising factor for capital flows, thereby improving trilemma trade-offs.

In its famous manual, Blanchard (2017) first presents the usual view that "under fixed exchange rates, the central bank gives up monetary policy as a policy instrument" (p.424) before moving to more realistic considerations in the appendix of chapter 19: "with imperfect capital mobility, a country has some freedom to move the domestic interest rate while maintaining its fixed exchange rate. This freedom depends primarily on three factors: […] the willingness of investors to shift between domestic and foreign assets, […] the degree of capital controls, […] the amount of foreign exchange reserves it holds" (Blanchard, 2017: 430).

[4] This asymmetry was also noted several authors, including De Grauwe (1997).

Economists affiliated to the Modern Money Theory approach (MMT) usually support flexible exchange rate arrangements as a central feature of monetary sovereignty. It is therefore all the more remarkable to read the following excerpt from Wray (2015):

> "Above we argued that a floating exchange rate provides the greatest domestic policy space, while a fixed exchange rate normally reduces that space – unless, like China, sufficient foreign currency reserves are accumulated to remove any doubt that the peg can be maintained." (p.176)

The ability of reserves to improve monetary policy space is also emphasised by Bianchi & Sosa-Padilla (2020). Using a model of endogenous sovereign default, the authors find that "when the government issues debt to accumulate reserves, this does not necessarily lead to increases in spreads" (p.2). This is because accumulated reserves can be useful to mitigate higher borrowing costs when borrowing conditions are particularly adverse. As a result, the authors conclude that "a government that increases its debt, but accumulate reserves at the same time, may not see increases in the cost of borrowing" (p.2).

The dilemma approach

Another major claim regarding the evolution of the trilemma comes from Hélène Rey (2013, 2016) according to whom the existence of a global financial cycle hinders the ability of variable exchange rate regimes to insulate countries from external shocks, which can only be sheltered by using capital controls or prudential measures. From this, Rey (2013) concludes that the monetary policy trilemma has morphed into a dilemma, whereby the only choice lies between foregoing autonomous monetary policies or implementing measures to reduce capital mobility[5].

Rey's approach can be found in several complementary papers. To measure the global financial cycle, Rey (2013) highlights the existence of co-movements of capital flows within a sample of 49 countries. She also identifies the global financial cycle as being tightly and negatively related to the VIX – which is an index calculated using the prices of S&P 500 options to generate a 30-day forward projection of volatility. Rey (2016) further identifies three mechanisms or (sub)channels: an "international credit channel" operating through collateral constraints, a "risk-taking channel" that relies on the synchronisation and compression of risk premia around the world, and a "fear of floating channel" stemming from potentially disruptive central bank reactions.

[5] It is worth mentioning that Bianchi & Lorenzoni (2021) consider a "prudential use" of FX reserves, which they see as a substitute for capital controls.

Using a cross section of 858 risky asset prices distributed on five continents, Miranda Agrippino & Rey (2015) show that 25% of the variance of risky returns can be explained by a "global factor" for which they effectively use the VIX as a proxy. Passari & Rey (2015) regress stock market returns and domestic credit to GDP market returns on a combination of explanatory variables including the VIX and a classification of exchange rate regimes divided into four categories ranging from hard peg (1) to free float (4), across 4 periods (1990-2013, 1990-2007, 2000-2007, 2007-2013) and the same 49 countries as Rey (2015).

A major flaw of the dilemma approach comes from the sample of countries used, which is heavily skewed in favour of developed countries. Out of 49 countries used by Passari & Rey (2015), 20 of them are European, and while Asian countries include China and Indonesia, India is not included. Furthermore, most of the European countries either belongs to the Eurozone or have been pegged to the euro – like Denmark. As a result, category 1 consists mostly of the Eurozone, as well as a few other countries such as China during the de facto fixed peg period, and Argentina during the currency board era. The sampling bias is even more pronounced in Miranda-Agrippino (2015) which do not include Asian emerging economies, or any Latin American country at all. As a result, the 'global financial channel' ought to be renamed 'first-world financial channel'.

While thought-provoking, Rey's dilemma conjecture has been since refuted in several works. Using a sample of 40 emerging markets over the period 1986-2013, Obstfeld & al (2017) find that countries with fixed exchange rate regimes are more likely to experience financial vulnerabilities than those with relatively flexible regimes. Using a sample spanning across 161 countries from 1970 to 2013, and multiple specifications, Ligonnière (2018) obtains several key results. Firstly, he finds that monetary policy autonomy is mainly driven by financial openness and the exchange rate regime – which invalidates the dilemma claim. Secondly, he finds that the addition of FX reserves as a control variable improves the quality of the estimation, which supports Aizenman's quadrilemma claim. Finally, Ligonnière finds that the sensitivity to the global financial cycle depends less on the fluctuations of the VIX than on the presence of global investors and global banks in the different countries.

Dominant currency paradigm

A last branch of the recent international macroeconomic literature highlights the existence of a "dominant currency paradigm" (Gopinath & al. 2020, Gopinath & Itskokhi 2021) and analyses the implications of financing and price setting using the currencies of core countries, particularly the US dollar. While the traditional Mundellian approach is based on producer currency pricing (also known

as local or exporter currency pricing), this new approach acknowledges the dominance of a small number of currencies in global financing and pricing practices. As far as the monetary policy trilemma is concerned, the implications of borrowing and setting prices in dominant currencies are twofold. Firstly, the use of dominant currency renders domestic monetary policy less effective, as it cannot influence the financing conditions of agents borrowing in external dominant currencies. Secondly, exchange rate depreciation can prove problematic when domestic liabilities are denominated in foreign currency, as their value expressed in domestic currency will increase.

The effect of dominant currency practices on the theoretical choice of a n-lemma is not clear-cut. On the one hand, it could be argued that dominant currency usage underpins a theoretical move towards the dilemma, since changes in the interest rates associated with the domestic currency have less effect on domestic financing conditions – thereby crippling the trilemma. On the other hand, the use of dominant currencies in pricing and financing processes strengthen the case for peripheric countries to accumulate international reserves as a way of insuring themselves against external financial instability, by becoming their own international lender of last resort. Using their "integrated policy framework", Basu & al. (2020) find that FX intervention makes sense in the context of dominant currency pricing, especially when the debt in external currency is high[6].

In light of the previous considerations, I believe the case for turning the trilemma into a quadrilemma is much stronger than the case for the dilemma. This is not to say that Rey's approach should be dismissed altogether, but as far as the characterisation of a n-lemma is concerned, the quadrilemma approach appears more relavant.

[6] In any case, the degree of currency dominance varies across space and time: the more dominated a country, the more constrained the trade-off between policy objectives, while countries with dominant currencies shall face less constraints.

V. A statement of the quadrilemma

Let us now turn to a synthetic exposition of the quadrilemma. As a starting point, the central bank intervenes on the spot market to influence the exchange rate. Noting xr the exchange rate defined as the number of unit of foreign currency per unit of domestic currency, CA the sum of the current and capital accounts[7] (see IMF 2009), NFI the net financial inflows – i.e. the financial account excluding changes in official reserves – and FXR the amount of official FX reserves, we have the following relation:

$$\Delta xr = \alpha\,(CA + NFI - \Delta FXR) \qquad (5.1)$$

Where α is a positive function, meaning that in the absence of FX intervention by the central bank, a net inflow will lead to exchange rate appreciation, while a net outflow will provoke an exchange rate depreciation. Due to minus sign, an increase in the FX reserves will lead to a lower exchange rate, while pushing the exchange rate up will necessitate a reduction in reserves.

This relation describes the relationship between exchange rate and reserves in most exchange rate regimes. For instance, a perfectly fixed peg ($\Delta xr = 0$) involves allowing FX reserves to fluctuate without restriction to match the net inflows or outflows. On the other hand, adopting a perfectly floating regime involves leaving the reserves untouched ($\Delta FXR = 0$). Intermediate possibilities include managed floating, where reserve variations are used to smooth exchange rate fluctuations, or crawling peg, where a targeted variation of the exchange rate will determine the extent of reserve use.

As a second step, I assume that at any point NFI are, among other things, a function of the differential between national and foreign interest rates ($r_{DOM} - r_{ROW}$) where, r_{DOM} is the vector of domestic interest rates, r_{ROW} is the vector of foreign interest rates, and NFI is a decreasing function of the interest rate differential – no assumption is made about the slope and intercept of NFI.

Finally, I note β the degree of mobility of capital between countries: $\beta = 1$ means that capitals flow freely between countries, while $\beta = 0$ corresponds to a situation where capital controls prevent investors from entering or leaving the country at short notice.

[7] I assume that all the transactions are monetary, i.e. none of them takes place in kind as this would skew the equality.

Combining the previous elements, we obtain the following equation to identify the monetary policy quadrilemma:

$$\Delta xr = \alpha\ (CA + \beta\ .\ NFI\ (i - i^{*})\ -\ \Delta FXR) \qquad (5.2)$$

According to equation [2], and assuming for the sake of simplicity that $CA = 0$, it is possible to maintain a fixed exchange rate, i. e. $\Delta xr = 0$, if at least one of the following conditions is satisfied:

a) The exchange rate is insensitive to net FX flows, $i.e.\ \ \alpha(\ ) = 0$.
b) Capital controls are enforced, $i.e.\ \beta = 0$.
c) Capital flows are insensitive to interest rate differentials, $i.e.\ \ k(\ ) = 0$.
d) Domestic interest rates adjust so that $NFI\ (i - i^{*}) = 0$, which is tantamount to saying monetary policy is constrained.
e) Reserves can vary to compensate for new FX flows, $i.e.\ \ \Delta R = \ \beta\ .NFI\ (i - i^{*})$.

Options a) and c) are usually ruled out, due to the implicit assumption that price-elasticities of supplies and demands for financial assets are different from zero. Therefore, possibilities b), d) and e) remain to stabilise the exchange rate: capital controls, interest rate adjustment, and use of reserves.

We can therefore establish the following quadrilemma[8]:

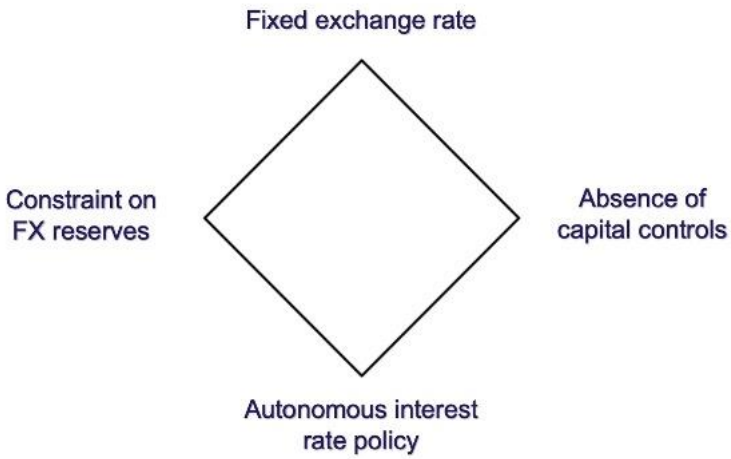

Figure 2: Quadrilemma graphical representation

According to Figure 2, three of the four corners can be simultaneously met, which means:

- There is scope for leading an autonomous interest rate policy in the context of a fixed peg, even in the absence of capital controls, as long as FX reserves are sufficient (particularly in the case of net outflows).
- If there is a constraint on FX reserves, one of the other dimensions will have to give in, which reactivates the classical trilemma.

[8] This quadrilemma is formulated in terms of policy tool availability, whereas Aizenman's quadrilemma is formulated in terms of policy objectives (Aizenman 2013, 2019). Note that I use 'interest-rate policy' instead of 'monetary policy'. 'Constraint on FX reserves' can be economic (low or depleted reserves), political (unwillingness to make an active use of reserves) or legal.

VI. A simple modelling of the quadrilemma

> "In a context of free capital mobility, the central bank can simultaneously control the exchange rate and the interest rate. This runs directly counter to what is claimed by the so-called "trilemma" of an economy open to capital movements. Here we argue that this trilemma is false in certain circumstances and, consequently, is false as a general theorem."
> Frenkel (2007, p.30)

In this section, I provide a simple model[9] to display the most extreme application of the quadrilemma, that is the possibility of bypassing the trilemma altogether, in line with Frenkel's quote above. I use a two-country stock-flow consistent (SFC) model[10] consisting of two countries linked by a fixed exchange rate arrangement: DOM and ROW. The exchange rate is normalised to 1 and does not appear explicitly in the equations. The structures of the stocks and flows of the two-country economy are illustrated by the following matrices:

BALANCE SHEETS									
	DOM				**ROW**				
	Households	Firms	Govt.	Central bank	Households	Firms	Govt.	Central bank	Sum
DOM bills	$+B^{DOM}_{HH_{DOM}}$		$-B^{DOM}$		$+B^{DOM}_{HH_{ROW}}$			$+B^{DOM}_{CB_{ROW}}$	0
ROW bills	$+B^{ROW}_{HH_{DOM}}$			$+B^{ROW}_{CB_{DOM}}$	$+B^{ROW}_{HH_{ROW}}$		$-B^{ROW}$		0
DOM ccy	$+M^{DOM}_{HH_{DOM}}$		$+M^{DOM}_{GOV_{DOM}}$	$-M^{DOM}$					0
ROW ccy					$+M^{ROW}_{HH_{ROW}}$		$+M^{ROW}_{GOV_{ROW}}$	$-M^{ROW}$	0
Balance	$-V_{DOM}$		$+D_{DOM}$	$NW_{CB_{DOM}}$	$-V_{ROW}$		$+D_{ROW}$	$NW_{CB_{ROW}}$	0
Sum	0		0	0	0		0	0	0

Table 2: Stock matrix

[9] The model, entirely coded in visual basic, is available on request.

[10] The main influence for this model is chapter 6 from Godley & Lavoie (2012). The pioneers of SFC modelling are Allen & Kenen (1980) and Godley & Cripps (1983), although SFC modelling really took off under Godley & Lavoie's lead in the late 90s and the 2000s. The last decade has witnessed the emergence of a significant SFC literature. Important recent developments include Caiani & al. (2016), Raza & al. (2019), Byrialsen & Raza (2020), Valdecantos (2020), Mazier (2020), Godin & Yilmaz (2020).

INCOME – EXPENDITURE TRANSACTIONS									
	DOM				ROW				
	Households	Firms	Govt.	Central bank	Households	Firms	Govt.	Central bank	Sum
Consumption	$-C_{DOM}$	$+C_{DOM}$			$-C_{ROW}$	$+C_{ROW}$			0
Govt. Exp.		$+G_{DOM}$	$-G_{DOM}$			$+G_{ROW}$	$-G_{ROW}$		0
Trade		$+X_{DOM}$				$-IM_{ROW}$			0
		$-IM_{DOM}$				$+X_{ROW}$			0
GDP	$+Y_{DOM}$	$-Y_{DOM}$			$+Y_{ROW}$	$-Y_{ROW}$			0
Interest payments	$+B^{DOM}_{HH_{DOM}} * r_{DOM}$		$-B^{DOM} * r_{DOM}$		$+B^{DOM}_{HH_{ROW}} * r_{DOM}$			$+B^{DOM}_{CB_{ROW}} * r_{DOM}$	0
	$+B^{ROW}_{HH_{DOM}} * r_{ROW}$			$+B^{ROW}_{CB_{DOM}} * r_{ROW}$	$+B^{ROW}_{HH_{ROW}} * r_{ROW}$		$-B^{ROW} * r_{ROW}$		0
Taxes	$-T_{DOM}$		$+T_{DOM}$		$-T_{ROW}$		$+T_{ROW}$		0
CB profits			$+Div_{DOM}$	$-Div_{DOM}$			$+Div_{ROW}$	$-Div_{ROW}$	0
FLOW OF FUNDS TRANSACTIONS									
DOM bills	$-\Delta B^{DOM}_{hh_{DOM}}$		$+\Delta B^{DOM}$		$-\Delta B^{DOM}_{hh_{ROW}}$			$-\Delta B^{DOM}_{CB_{ROW}}$	0
ROW bills	$-\Delta B^{ROW}_{hh_{DOM}}$			$-\Delta B^{ROW}_{CB_{DOM}}$	$-\Delta B^{ROW}_{hh_{ROW}}$		$+\Delta B^{ROW}$		0
DOM ccy	$-\Delta M^{DOM}_{hh_{DOM}}$		$-\Delta M^{DOM}_{gov_{DOM}}$	$+\Delta M^{DOM}$					0
ROW ccy					$-\Delta M^{ROW}_{hh_{ROW}}$		$-\Delta M^{ROW}_{gov_{ROW}}$	$+\Delta M^{ROW}$	0
Balance	0		0	0	0		0	0	0

Table 3: Flow matrix

Model specification

The equations governing production in both countries are standard. Production (Y) is the sum of household consumption (C), Government expenditure (G), and the trade balance (X – IM). Household consumption is a function of their disposable income (YD) and lagged wealth ($V_{(-1)}$). Government expenditure is a constant. Exports are determined by the other country's imports, which are a linear function of production.

$$Y_i = C_i + G_i + X_i - IM_i \tag{6.1}$$

$$C_i = \alpha_{1i} * YD_i + \alpha_{2i} * V_{i(-1)} \tag{6.2}$$

$$G_i = \overline{G}_i \tag{6.3}$$

$$X_i = IM_j \tag{6.4}$$

$$IM_i = \mu_i * Y_i \tag{6.5}$$

Where, for each country i, α_{1i} is the propensity to consume out of disposable income, α_{2i} the propensity to consume out of wealth, μ_i the propensity to import, and j denotes the other country.

Since firms do not retain any earnings, the value of production goes to households in the form of income. Household gross income (YG) is therefore the sum of production and interest income on domestic and foreign debt. Disposable income (YD) equals gross income minus income tax (T), itself a linear function of gross income (noting θ the income tax rate):

$$YG_i = Y_i + r_{i(-1)} * B^i_{hh_i(-1)} + r_{j(-1)} * B^j_{hh_i(-1)} \quad (6.6)$$

$$T_i = \theta * YG_i \quad (6.7)$$

$$YD_i = YG_i - T_i \quad (6.8)$$

When noting amounts of monetary and financial assets, the main letter relates to the type of asset: M in the case of currency (money), B in the case of bills. The superscript pertains to the issuer. Since each type of asset can be issued by one issuer (the central bank in the case of currency, the Government in the case of bills), only the country is mentioned. The subscript indicates who holds the asset: household or Government in the case of currency, household or central bank in the case of bills. The number between brackets indicates the extent of the lag. Therefore, $B^i_{hh_i(-1)}$ is the amount that households of country i held in the form of their government's bills at the end of the previous period, and $B^j_{hh_i(-1)}$ the amount they held in the form of foreign Government's bills. $r_{i(-1)}$ is the yield on domestic bills in the previous period and $r_{j(-1)}$ the yield on foreign bills.

The variation of households' wealth is equal to the difference between their disposable income and consumption. Households in each country allocate their wealth between domestic bonds, foreign bonds and domestic currency. The share of wealth allocated to each type of asset (e.g. bills issued by the Government of country k) follows a Tobinesque process, whereby it is equal to the sum of a fixed proportion ($\lambda^{k,0}$) and variable increments depending on the respective yields on domestic (λ^{k,r_i}): and foreign bills (λ^{k,r_j}):

$$\Delta V_i = YD_i - C_i \quad (6.9)$$

$$B^k_{HH_i} = V_i * \left(\lambda^{k,0}_{HH_i} + \lambda^{k,r_i}_{HH_i} * r_i + \lambda^{k,r_j}_{HH_i} * r_j \right) \quad (6.10)$$

$$M^i_{HH_i} = V_i - B^i_{HH_i} - B^j_{HH_i} \quad (6.11)$$

The modelling of the endogenous money process associated with interest rate targeting[11] relies on a distinction between fundamental and market Government debt – respectively noted D_i and B_i, with i representing the country. Fundamental Government debt, or Government financing needs, is equal to the sum of past Government deficits. It differs from market Government debt which is the sum of Government bills issued on demand, held by households of both countries and the central bank of the other country. The two variables B and D can differ in size, based on portfolio preferences and the financing needs of the Government. The difference between market and fundamental Government debt corresponds to the balance of the Government at its central bank (ΔM_{GOV}). When market debt is greater than fundamental debt, the Government holds excess funds as central bank reserves. When fundamental debt is greater than market debt, the Government incurs an overdraft at its central bank. We assume that both reserves and the overdraft yield zero interest[12]. Finally, both central banks transfer their interest income earned on their international reserves to their government in the form of a dividend (Div).

$$\Delta D^i = G_i - T_i + r_{i(-1)} * B^i_{(-1)} - Div_i \tag{6.12}$$

$$\Delta B^i = B^i_{hh_i} + B^i_{hh_j} + B^i_{cb_j} \tag{6.13}$$

$$\Delta M^i_{gov_i} = \Delta B^i - \Delta D^i \tag{6.14}$$

$$Div_i = r_{j(-1)} * B^j_{cb_i(-1)} \tag{6.15}$$

The current account of country i (CA_i) is the sum of the trade account and the international income account, i.e. net interest income. The financial account of country i (FA_i) is the sum of the changes in foreign households and central bank holdings of domestic bills, minus the changes in domestic households' holdings of foreign bills.

$$CA_i = X_i - IM_i + r_{j(-1)} * \left(B^j_{hh_i(-1)} + B^j_{cb_i(-1)}\right) - r_{i(-1)} * \left(B^i_{hh_j(-1)} + B^i_{cb_j(-1)}\right) \tag{6.16}$$

$$FA_i = \Delta B^i_{HH_j} + \Delta B^i_{CB_j} - \Delta B^j_{HH_i} \tag{6.17}$$

[11] This form of endogenous money, associated with changes in the holding of domestic bonds by the central bank, must be distinguished from endogenous money arising from credit lending by commercial banks – which is absent from this model.

[12] Denmark offers an example of this type of arrangement: the Danish Government issues more debt than it needs to for strictly financing motives and saves the excess amount at the Danish central bank (Danish Nationalbank 2021b).

Since the central bank of ROW has no exchange rate target, it does not intervene on the foreign exchange market, thus keeping its foreign reserves constant. The burden of adjustment falls entirely onto DOM's central bank.

$$\Delta B_{CB_{ROW}}^{DOM} = 0 \tag{6.18}$$

$$\Delta B_{CB_{DOM}}^{ROW} = CA_{DOM} + FA_{DOM} \tag{6.19}$$

By assumption, the two countries have always had a fixed exchange rate arrangement and their current accounts have always been equal to zero in the past. Initial foreign reserves are assumed to come from a currency exchange between the two central banks at an indefinite point in the past. The two countries have therefore initially the same amount of FX reserves, regardless of their relative size[13].

Monetary authorities of DOM target both the domestic interest rate and the exchange vis-à-vis the rest of the world, while the monetary authorities of ROW target the foreign interest rate. Sterilisation of FX reserves by DOM occurs as a by-product of these policy stances. For example, a reduction in DOM's interest rate leads to investors, both domestic and foreign, selling DOM's securities to buy ROW securities instead. On the one hand, DOM's central commits to buying as many domestic securities as needed to stabilise the interest rate at its new, low level. On the other hand, its commitment to maintaining a fixed exchange rate leads DOM's central bank to sell as many FX reserves as needed. As a result, the size of DOM's balance sheet does not change, but its composition does: foreign securities are replaced with domestic ones.

Country configurations and portfolio setups

Three configurations are considered, corresponding to different relative sizes of the two countries. In the first scenario, the two countries are the same size and have perfectly symmetric portfolio coefficients ("Symmetry DOM/ROW") with no home bias in the holding of bills. In the second scenario, DOM is half as big as ROW ("Small DOM"), while the opposite happens in the third scenario, where DOM is twice as big as ROW ("Big DOM"). Note that, due to stock consistency, it is impossible to maintain symmetry in portfolio coefficients when the two countries are not the same size. It is a mathematical necessity that the biggest country – DOM or ROW depending on the scenario – must hold proportionately more of its bills than it does the other country's bills.

[13] It is also a logical necessity when dealing with the symmetric scenario described further.

In the symmetric scenario, the households in each country start with a total portfolio of 100, that breaks down into 44 held in bills of their country, 44 held in bills of the other country, and 12 held in currency – to simplify, it is assumed that households cannot hold the other country's currency. In the asymmetric scenarios, the 44-44-12 breakdown in household portfolio still applies to the small country, but the households of the big country whose total portfolio is twice as big hold 132 in the form of bills of their country, 44 in bills of the small country, and 24 in their country's currency.

In all the scenarios, the central bank of each country starts with FX reserves of 12, held in the form of the other country's bills. Since we assume that DOM unilaterally pursues a fixed exchange rate, DOM's reserves vary to absorb net flows consecutive to changes in its interest rate, while ROW's reserves remain constant. As far as the public sector's balance sheet is concerned, a difference between the symmetric and asymmetric scenarios stems from the amount of Government reserves at the central bank. Keeping the weight of currency in the households' portfolio equal between the two countries, while assuming the same amount of FX reserves in the two countries implies that the net position of the Government of the larger country with its central bank must be lower than the position of the Government of the small country.

Introducing the shocks

In all the iterations of the model, interest rates in DOM and ROW are initially set to 2%. Two types of shocks are considered, both consisting of unanticipated variations in DOM's interest rate: the first one is an increase to 3%, the second one is a reduction to 1%.

When DOM decreases its interest rate, investors from both countries react by selling DOM bills, buying ROW bills and increasing their holdings of currency. Since households can only hold currency from their own country, the decrease in the holdings of DOM bills by ROW investors will fully translate into higher demand for ROW assets – bills or currency – while the decrease in the holdings of DOM bills by DOM investors will only partly give way to capital outflows, since their demand for DOM currency will increase too.

The initial shock on DOM's FX reserves is therefore entirely due to the financial account, through changes in holdings of assets:

$$\Delta \mathrm{B}^{\mathrm{ROW}}_{\mathrm{CB}_{\mathrm{DOM}}} = \mathrm{FA}_{\mathrm{DOM}} = -\Delta \mathrm{B}^{ROW}_{\mathrm{HH}_{\mathrm{DOM}}} - \Delta \mathrm{B}^{\mathrm{ROW}}_{\mathrm{HH}_{\mathrm{ROW}}} - \Delta \mathrm{M}^{\mathrm{ROW}}_{\mathrm{HH}_{\mathrm{ROW}}} \qquad (6.20)$$

In the case of an increase in DOM's interest rate, the opposite happens: investors will buy DOM bills, sell ROW bills and reduce their holdings of currency. This leads the government of DOM to issue

additional public debt to accommodate the demand – otherwise, the interest rate would have to decrease back to its initial level.

The transmission of the shock happens through the same channel across all configurations, i.e. regardless of the relative size of the two countries – only the magnitude differs. Figure 3 shows the evolution of DOM's FX reserves in the six scenarios – each corresponding to a different shock/configuration combination:

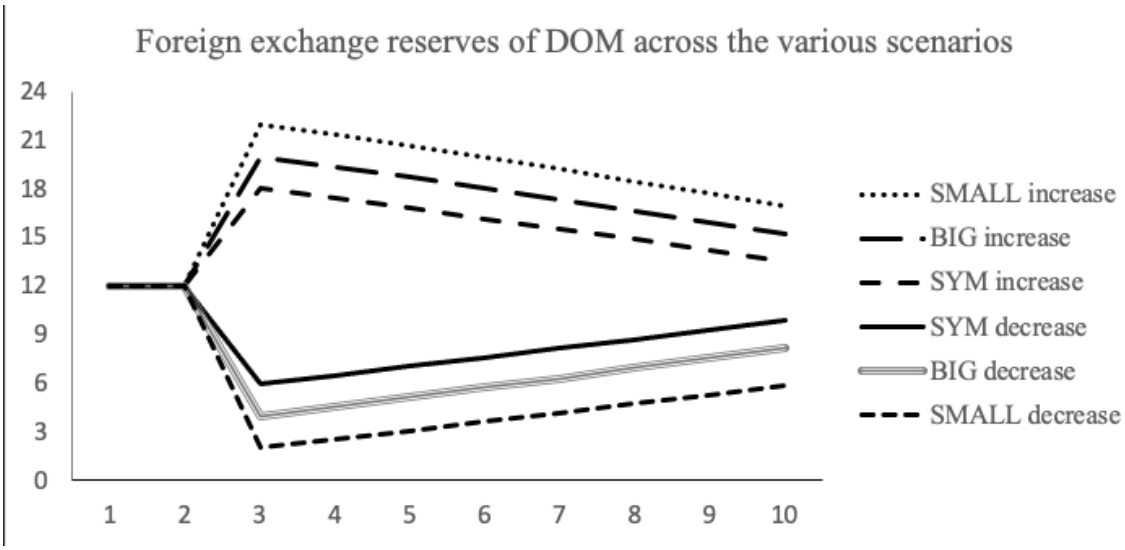

Figure 3: FX reserves following the shock in the various scenarious

Short term effects

In the short run, a rise in the interest rate of DOM brings about an increase in DOM's FX reserves, while a reduction in its interest rate provokes a decrease in its FX reserves. The initial shock is larger in the case when DOM is a small country – although interestingly the effect is stronger when DOM is the big country, compared to the symmetric configuration.

In none of the scenarios is the initial FX reserve variation big enough to deplete the reserves. This is due to a combination of several factors, which can be identified by combining equations (6.20) and (6.10):

$$B^{ROW}_{CB_{DOM}} \geq \lambda^{ROW,r_{DOM}}_{HH_{DOM}} * \Delta r_i * V_i + \lambda^{DOM,r_{DOM}}_{HH_{ROW}} * \Delta r_i * V_j \qquad (6.21)$$

The effect of the shock on DOM's FX reserves depends on investors' sensitivity to changes in yields, the change in interest rates, and the level of wealth in the two countries. In other words, in the short

run the trilemma can be bypassed as long as reserves are high enough, considering the change in interest rate, the degree of asset substitutability and the level of wealth in the two countries.

If the initial FX reserves are not sufficient to cushion the capital outflows, DOM will either have to let its interest rate increase or resort to external refinancing from ROW's central bank, for instance in the form of swap lines.

Longer term effects

As can be seen on Figure 3, the initial effect quickly reverses: a negative interest rate variation gives way to an increase in FX reserves, and vice versa. This is because the interest rate differential starts having an impact on the current account – and the initial financial account effect was a one-off. After a reduction in DOM's interest rate, DOM will pay less to ROW than it will receive, while the opposite will be the case following a rise in its interest rate. This means that in the long run, the pure effect of portfolio reallocation is the opposite of the short run effect: an interest rate reduction would end up 'paying for itself' while an interest rate increase would eventually lead to the depletion of FX reserves[14].

We therefore seem to observe an 'overshooting' of foreign exchange reserves – whereby a sharp initial variation in FX reserves is followed in the longer run by slower variations in the opposite direction – somewhat reminiscent of the exchange rate overshooting identified by Dornbusch (1976). However, Dornbusch relies on strict uncovered interest parity and short-term price stickiness of real goods and services and the exchange rate tends towards an equilibrium value in the long term – while this model makes no assumption on interest rate parity or price rigidity[15], the exchange rate is constant and the level of FX reserves does not converge when solely determined by investors' preferences.

Table 4 reports the changes in selected variables across all scenarios and shocks. In each case, the first figure indicates the absolute change in each variable (with the associated percentage between brackets underneath), while the second figure shows the incremental variation over the next 5 periods (that is, from t+1 to t+6, t being the period at which the shock occurs). This allows to see which variables keep on going in the same direction and which ones change trajectory once the initial effect of the shock wears off.

[14] Note that the slope of the change in FX reserves is the same across all country configurations associated with a given shock. This is because the initial level of FX reserves is identical across all scenarios, and so is the interest rate differential for each type of shock.

[15] The nominal approach of the model assumes implicitly a cross-elasticity of demand to price algebraically equal to -1.

Reflections on the limits of the model

This model focuses on the effects of interest rate changes on portfolio allocation, which is the phenomenon underpinning interest rate parity arbitrage and the monetary policy trilemma. To keep the rest of the model simple, I only considered nominal variables, and production does not include a gross capital formation component. If we accept the idea that, in actual reality, changes in central bank interest rates affect financial decisions much earlier than decisions pertaining to the production of real goods and services, then this model can be considered a reasonable approximation as far as short-run analysis is concerned[16]. Its relevance for longer-run analysis is more questionable, since the model only considers the pure long-run effect of portfolio changes, in the absence of effects of monetary policy on the real side of the economy.

[16] This is also in line with Patel & Cavallino's (2019) survey finding that an average FX intervention is seen as reaching its highest effect in the short term (2 to 8 weeks) before declining.

Variable	Scenario	1% decrease in DOM interest rate		1% increase in DOM interest rate	
		Shock effect	Further 5 periods	Shock effect	Further 5 periods
DOM households' holdings of DOM bills	Symmetry DOM/FOR	↓ 4.00 (-9.1%)	↓ 0.09 (-0.2%)	↑ 4.00 (+9.1%)	↑ 0.13 (+0.3%)
	Small DOM	↓ 4.00 (-9.1%)	↓ 0.08 (-0.2%)	↑ 4.00 (+9.1%)	↑ 0.12 (+0.3%)
	Big DOM	↓ 8.00 (-6.1%)	↓ 0.41 (-0.3%)	↑ 8.00 (+6.1%)	↑ 0.53 (+0.4%)
DOM households' holdings of ROW bills	Symmetry DOM/FOR	↑ 2.00 (+4.5%)	↓ 0.10 (-0.2%)	↓ 2.00 (-4.5%)	↑ 0.11 (+0.3%)
	Small DOM	↑ 2.00 (+4.5%)	↓ 0.10 (-0.2%)	↓ 2.00 (-4.5%)	↑ 0.11 (+0.3%)
	Big DOM	↑ 4.00 (+9.1%)	↓ 0.16 (-0.3%)	↓ 4.00 (-9.1%)	↑ 0.15 (+0.4%)
DOM households' holdings of DOM currency	Symmetry DOM/FOR	↑ 2.00 (+16.7%)	↓ 0.03 (-0.2%)	↓ 2.00 (-16.7%)	↑ 0.03 (+0.3%)
	Small DOM	↑ 2.00 (+16.7%)	↓ 0.03 (-0.2%)	↓ 2.00 (-16.7%)	↑ 0.03 (+0.3%)
	Big DOM	↑ 4.00 (+16.7%)	↓ 0.09 (-0.3%)	↓ 4.00 (-16.7%)	↑ 0.08 (+0.4%)
DOM Foreign Exchange Reserves	Symmetry DOM/FOR	↓ 6.00 (-50.0%)	↑ 2.72 (+45.3%)	↑ 6.00 (+50.0%)	↓ 3.11 (-17.3%)
	Small DOM	↓ 10.00 (-83.3%)	↑ 2.72 (+135.7%)	↑ 10.00 (+83.3%)	↓ 3.52 (-16.0%)
	Big DOM	↓ 8.00 (-66.7%)	↑ 2.94 (+73.5%)	↑ 8.00 (+66.7%)	↓ 3.31 (-16.6%)
ROW households' holdings of DOM bills	Symmetry DOM/FOR	↓ 4.00 (-9.1%)	↓ 0.09 (-0.2%)	↑ 4.00 (+9.1%)	↑ 0.13 (+0.3%)
	Small DOM	↓ 8.00 (-18.2%)	↓ 0.04 (-0.1%)	↑ 8.00 (+18.2%)	↑ 0.09 (+0.2%)
	Big DOM	↓ 4.00 (-9.1%)	↓ 0.10 (-0.2%)	↑ 4.00 (+9.1%)	↑ 0.14 (+0.3%)
ROW households' holdings of ROW bills	Symmetry DOM/FOR	↑ 2.00 (+4.5%)	↓ 0.10 (-0.2%)	↓ 2.00 (-4.5%)	↑ 0.11 (+0.3%)
	Small DOM	↑ 4.00 (+3.0%)	↓ 0.17 (-0.1%)	↓ 4.00 (-3.0%)	↑ 0.21 (+0.2%)
	Big DOM	↑ 2.00 (+4.5%)	↓ 0.11 (-0.2%)	↓ 2.00 (-4.5%)	↑ 0.12 (+0.3%)
ROW households' holdings of ROW currency	Symmetry DOM/FOR	↑ 2.00 (+16.7%)	↓ 0.03 (-0.2%)	↓ 2.00 (-16.7%)	↑ 0.03 (+0.3%)
	Small DOM	↑ 4.00 (+16.7%)	↓ 0.03 (-0.1%)	↓ 4.00 (-16.7%)	↑ 0.03 (+0.2%)
	Big DOM	↑ 2.00 (+16.7%)	↓ 0.03 (-0.2%)	↓ 2.00 (-16.7%)	↑ 0.03 (+0.3%)

Figure 4: Selected variable changes

VII. Conclusion

The addition of FX reserves to the macroeconomic policy toolkit turns the monetary policy trilemma into a quadrilemma. After discussing some of the literature on foreign exchange reserves, the dilemma approach, the dominant currency paradigm, I have put forward a presentation of the quadrilemma based on a single equation encompassing the four dimensions to consider: exchange rate fixity, absence of capital controls, autonomous interest rate policy, and constraints on FX reserves.

To illustrate this claim, I have used a simple SFC model, which has highlighted different dynamics in the short run and the long run. In the short run, the model shows that the trilemma does not hold in the case of an increase in the domestic interest rate, as long as the government is willing to issue public debt on demand.

In the case of an interest rate decrease, provided the central bank is willing to intervene on both foreign and domestic markets, it is possible to bypass the trilemma if the initial level of FX reserves is sufficient to absorb the capital outflows immediately resulting from the change in interest rate – the other determining factors being the change in interest, the investors' sensitivity to changes in relative yields, and the level of wealth in the two countries.

In the longer run, the initial financial account, stock-related effect is superseded by a current account, flow-related phenomenon, due to the change in net interest income occasioned by the interest rate differential. This leads to a progressive reversal of net financial position between the two countries. However, this is the consequence of looking at the pure effect of portfolio reallocation in the long term, to the exclusion of other channels such as investment or effects on prices. The long run conclusions of the model need to be taken with caution.

More research is needed in the field of international monetary policy to understand the conditions of application of the quadrilemma. Let me make a few suggestions:

- Adding more sectors and features to the model used here, especially to make it more realistic in the long run.
- Comparing local and dominant currency pricing and financing.
- Analysing the difference between sterilised and non-sterilised interventions, in relation with initial current account imbalances.
- Investigating the use of swap lines and other alternatives to FX reserve accumulation.
- Allowing for exchange flexibility to assess the existence of exchange rate overshooting in a context of imperfect asset substitutability.

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