Monetary policy normalization and global spillovers: the US, China and the rest

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Chatham House, London

Draft - October 2018

Abstract

We examine the impact of monetary policy normalization in the United States on global financial stability. We find that over the past three decades bouts of global financial instability have occurred each time the monetary policy cycle turned in the United States, so it looks hard to argue that this time will be different. We believe that this source of financial instability is endemic to the international monetary system as currently constructed, with vulnerabilities and exchange rate arrangements in emerging market economies, notably China, exacerbating global financial instability. We find that recurrent financial instability, the secular fall in interest rates and the secular increase in global debt tend to be mutually reinforcing, and that international coordination of monetary policies in the developed world can help mitigate these tendencies.

Introduction

The global financial crisis of 2008 revealed the extent of financial integration that was undertaken in the previous two decades and its adverse impact on welfare caused by financial instability. Monetary policy has played a key role both in the build-up of imbalances that led to the global financial crisis and, as well, as a response to the crisis. In response to the Great Recession in 2009, developed economies' monetary policies were eased at an unprecedented scale. This was led by the US, where the crisis struck first, followed by other developed economies. This opened up opportunities for carry trades, with capital flows bidding up financial assets across the globe. This was of course largely intended, with wealth gains assumed to support aggregate demand, but the longer-term implications are uncertain.

It was always feared that once the developed economies begin to take back monetary policy ease, financial stability would be threatened (Eichengreen and Gupta, 2014; Aizenman et al, 2014, Turner, 2017). First signs of turmoil emerged with the "taper tantrum" in 2013. With asset prices (e.g. the US stock market and also real estate across large swaths of the globe) having been boosted by super-low interest rates for a decade, a major downward correction in the face of a tightening of monetary policy was seen as a growing risk.

With the Fed normalization of monetary policy now well under way we explore its global spillover impact in a context where China is going through its own "constrained adjustment" and the level of debt globally is at an unprecedented high. The key tenet of our analysis is that by managing the exchange rate and implementing capital controls, China protects itself from spillover effects from Fed policy normalization and also constrains the power of US monetary policy. As a result, US monetary policy needs to "work harder" to cool down the domestic economy than it otherwise would, with concomitantly stronger spillovers on other countries where debt levels are high.

The upshot is that while the world's two largest Systemically Important Countries (SICs) are engaged in, respectively, normalizing monetary policy (the US) and large currency interventions (China), these two policies combined change investors' risk perception and pricing of risk. As investors dump emerging markets' assets, their policymakers face the dilemma between either aligning their monetary policy stances with those of the Fed – thus constraining output and increasing the costs of borrowing and of debt servicing and so the risk of financial instability – or keeping monetary policy loose – and thus fueling capital outflows with comparable if not the same financial instability implications.

Is there scope for international coordination to address this risk? How could this ease the trade-off between short-run macroeconomic stabilization goals and financial stability – i.e. stability of the financial system at large? Would policy coordination be welfare enhancing for all players (US, other developed and emerging economies, China), or just for a subset of them? To answer these questions, we develop a stylized global model in which one economy has features broadly mapped on those of the US – the largest SIC and the issuer of the key reserve currency, with an open capital account and a floating exchange rate. The other economies are mapped on China, a SIC that pegs its currency to the global reserve currency or a basket of developed economies' currencies, the euro area, and emerging market economies such as, for example, Brazil.

The paper is organized as follows. Part 1 reviews the current debate on the functioning of the international monetary system. In this section we examine China's 'constrained adjustment' and discuss how China's existing exchange rate arrangements and capital controls have become elements of disruption for the international monetary system. Part 2 focuses on the impact of normalization of US monetary policy on global financial stability. Here we discuss the transmission channels of financial instability and make a distinction between financial crises that originate in emerging market economies and are regional in terms of contagion and disruption (and hence require regional solutions) and financial crises that originate in the main financial centers and so are global. In Part 3 we address the question of international policy coordination through the development of the aforementioned stylized model. We consider also other potential triggers of macroeconomic and financial instability – such as Trump-trade policy, the rise of anti-EU sentiment in Italy and a debt accident in China. We conclude with an assessment of the policy options.

Part 1: Where we are coming from

It has become the mainstream view that the monetary and financial conditions of SICs has given rise to a "global financial cycle" (IMF, 2015). The financial spillover effects from SICs complicate the pursuit of domestic macroeconomic policy goals for non-systemically important developed economies and emerging markets and developing countries. In this section we review the mechanisms that produce this "global financial cycle".

1.a International liquidity and US monetary policy

The US is not like any other economy. It is the world's largest economy – even if in PPP terms it has been overtaken by China – with the largest and most liquid capital market and the key international currency. The US dollar, is the most liquid and most used currency in the world. The international monetary system as it emerged from the demise of Bretton Woods in the early 1970s – well before China entered the scene –revolves around the dollar. The supply of US dollars is the main source of global liquidity and the supply of US treasury bonds is the main source of risk-free financial assets. Hence, whenever monetary policy is eased in the United States, this boosts global liquidity via the injection of US dollars into the system via the US trade deficit and capital exports, as well as via the offshore euro dollar market. Monetary policy set by the FOMC thus has a powerful impact on exchange rates and, via the monetary policy reactions it triggers, interest rates in the developed world.

The impact on developing countries is significant as well. Most emerging market economies, with the exception of China, have open capital accounts and *de jure* floating exchange rates; those that need to finance their public debt on international capital markets tend to issue such debt in US dollars rather than in their own currencies – a situation that Barry Eichengreen et al (2002) define as "the original sin". In theory they should be able to pursue an independent monetary policy; in practice, however, they are confronted with the following dilemma.

1. Whenever US monetary policy is eased, capital flows go their way in search for higher returns, including in countries that are deemed to be financially more risky than the United States – hence with assets that command higher risk premia. Stronger capital inflows in developing countries on the back of US monetary policy tend to boost domestic asset prices, exchange rates and domestic credit growth. This is what happened in key emerging markets economies between 2009 and 2013. The policy response was – and remains – difficult. Policy makers may decide to relax monetary policy in order to curb the inflows and the exchange rate, but this may result in domestic overheating and excessive credit growth. Alternatively, they may decide to tighten monetary policy to stem domestic credit growth, but with the result of attracting even more capital inflows and strengthening the exchange rate and so making exports more expensive.
2. Conversely, whenever US monetary policy is reversed – or the Fed just signals the intention of reversing at a certain point in the future – this tends to trigger a sudden stop in the inflows, if not a stampede of capital to the exit in the case of the most vulnerable countries (see below). The result is that (some) emerging market economies are left in financial difficulties and their monetary policy is trapped in a dilemma. Easing could exacerbate the capital outflow and increase the cost of foreign-currency denominated credit while tightening would exacerbate the downturn in domestic demand. In addition, due to "the original sin", they have to face the exchange rate risk and rising costs of servicing and repaying the debt. Iacoviello and Navarro (2018) show that the impact on GDP in emerging economies is larger when vulnerability, measured using current account, foreign reserves, inflation, and external debt, is high. As these economies are exposed to volatile capital flows and occasional strong outflows, their exchange rate is very sensitive to divergences in monetary policy stances in the United States. This means that the band within which domestic interest rates can move against US rates is narrow. Therefore, the hands of the monetary authorities are tied despite a floating exchange rate.

1.b International liquidity and China's "constrained adjustments"

This picture gets more complicated when we include China. Despite becoming the world's largest exporter in 2010, a decade after joining the WTO, China lacks a fully-fledged international currency and is *de facto* free-riding the dollar-system. Until the monetary authorities began to internationalize the renminbi in the early 2010s, the Chinese currency had no international circulation because of the existing

restrictions on capital movements. Since 2010 the renminbi has grown its use in international trade (approximately 25% of China's trade is now settled in renminbi), in the payment system (the renminbi is now the eighth most used currency for international payments with 1% of total payments[1]) and in international finance through the renminbi offshore centers. Between 2010 and 2017 China's capital account has been considerably liberalized, even if through a system of quotas – "managed convertibility" as the then PBoC governor Zhou Xiaochuan defined it (IMFC, 2015). In response to strong capital outflows, capital controls were reintroduced in early 2017.

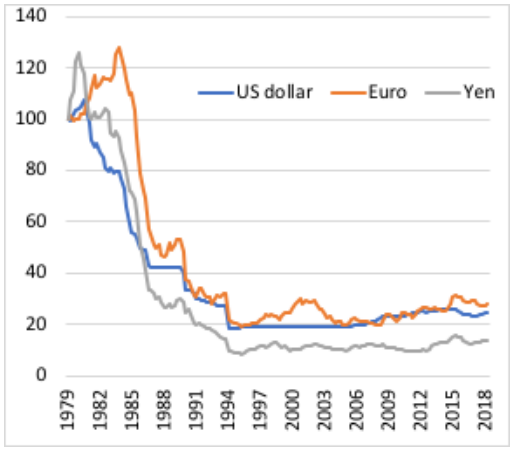
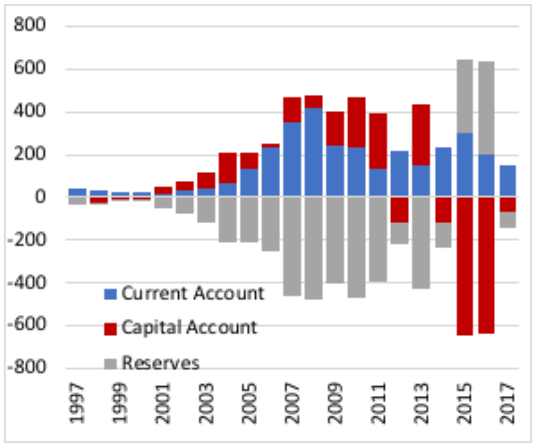
Since the mid 1990s China's exchange rate has been anchored to the dollar first and then to a basket of currencies – with the dollar holding the largest share – through a system of crawling pegging - to be replaced by dirty floating in more recent years. Before the crisis of 2008 this arrangement was dubbed "Bretton Woods 2" (Dooley, et al. 2003). Specifically, while China had shifted its peg to a basket of currencies in 2005, it moved back to the dollar peg in the aftermath of the financial crisis and maintained it through the critical 18 months during which the US Fed was implementing quantitative easing (QE). In June 2010 China reinstated the "managed floating exchange rate regime based on market supply and demand with reference to a basket of currencies" (People's Bank of China, June 19, 2010) and pegged the renminbi to a basket of currencies that, however, remained overweight US dollar.

Given the strong growth of the Chinese economy, between January 2010 and September 2014 the Chinese monetary authorities undertook extensive market intervention and purchases of dollars - and the consequent sterilization that resulted in $1.6 trillion added to the FX reserves - in order to keep the value of the renminbi in line with China's longer-term policy framework of export-led growth, with domestic demand contained by a comparatively high saving propensity. Specifically:

1. China kept its exchange rate fixed against the dollar for long stretches of time (Chart 1.1, Panel A), at a level that was structurally too low given the pace of output growth and the surplus in the trade balance. To maintain the exchange rate at the level consistent with China's long-term growth targets – i.e. structurally undervalued – required that the monetary authorities intervened in foreign exchange markets and purchase dollars.
2. The well-known 'Trilemma' predicts that to secure monetary policy independence – instead of being forced to accept whatever interest rate emerges from US monetary policy – China would have to keep its capital account closed (or at least manage it). Furthermore, constraints on capital mobility are necessary to protect the domestic banks against disruptive capital flows driven by diverging stances of monetary policy at home and in the US.
3. In addition, China's monetary authorities need to be able to sterilize their foreign exchange interventions so as to maintain monetary policy independence. For sterilized interventions to remain credible they need to be predominantly unidirectional (net purchases of foreign reserves), which requires that the current and capital accounts jointly remain in surplus – see Chart 1.1, Panel B). Large foreign exchange reserves holding can be used to support the exchange rate when it comes under downward pressure, as in more recent years.
4. As noted, the 'sterilization' of dollar inflows in the domestic market resulted in a large accumulation of official reserves between 2010 and 2014 – total reserve holding peaked at US$ 4.1 trillion in September 2014. Conversely, the 'sterilization' of dollar outflows resulted in a large disposal of official reserves between 2015 and 2017 – approximately US$ 1 trillion between the peak of September 2014 and mid-2017 (see again Chart 1.1, Panel B).

[1] The dollar is the most used, with 42.4% of international payments, followed by the euro with 36.2%, SWIFT (2018).

Chart 1.1: Exchange rate and balance of payments of China

A. Bilateral exchange rate of the renminbi against major currencies (index, 1979 Q1 = 100)	B. Balance of payments of China (bn US dollars)
	

Sources: IMF, OECD.

After 2013 China's policy approach has been aligned with the long-term plan of switching the model of growth from exports to domestic demand. As a result, the exchange rate arrangements have become more flexible and more market oriented, specifically with two reforms introduced in 2014 and in 2015.[2] However, the authorities are reluctant to embrace a fully floating exchange rate system that, combined with restricted capital movements, would allow to tailor monetary policy on the domestic economy and to reduce the international spillovers, as we will discuss in the rest of the paper. Instead they prefer to keep an inefficient and costly system with still significant scope for market intervention in support of the exchange rate.

1.c Implications for the "global financial cycle"

The literature on the "global financial cycle" asserts that while the country that issues the key reserve currency – or the currency of global banking (Miranda-Agrippino and Rey, 2018) – is the main driver, the macroeconomic frameworks that predominate in other SICs are equally important. On the one hand, the issuer of the key reserve currency keeps the global financial cycle in motion by maintaining diversified financial markets and holding no restrictions to capital movements. On the other hand, SICs other than the issuer of the key reserve currency, can keep the global financial cycle spinning by having a macroeconomic framework that is based on a managed exchange rate and constraints on capital movements (Subacchi and van den Noord, 2016; Rey, 2015; He et al., 2015; Shin, 2012).

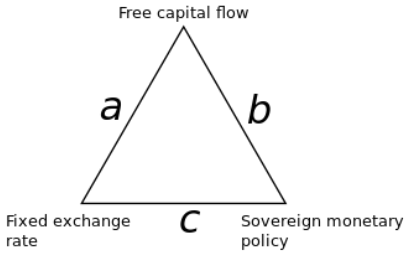
Miranda-Agrippino and Rey (2018) argue that global financial mobility limits domestic monetary policies in other economies regardless of the exchange rate regime, so that the "trilemma" – with free capital flows a country can pursue an independent monetary policy only if it has a floating exchange rate, see Chart 1.2 – no longer holds true. The "trilemma" has been a pillar of international macroeconomics in the last thirty years. But what happens when a SIC overcomes the "trilemma" and achieves to manage both the exchange rate and capital movements and yet to conduct monetary policy independently?

Based on our earlier work on spillovers and financial stability (Subacchi and van den Noord, 2012; Subacchi and van den Noord, 2016) we argue that China's rebuttal of the "trilemma" has forced US monetary policy to "work harder", especially in the years immediately after the crisis, so as to offset the

[2] In August 2015 the PBoC shifted the fixing of the exchange rate towards the market and away from policy-makers by allowing market-makers – 35 large banks – to submit prices for the reference rate based on the previous day's closing spot rate. At the same time, however, the PBoC cut the daily reference rate by 1.9%, triggering a 1.8% drop in the value of the renminbi.

lack of exchange rate adjustment against China. We looked at the interaction between the US and China and argued that they were on different sides of the Trilemma, with the US on side b and China on side c (Chart 1.2)

Chart 1.2: Trilemma or the Impossible Trinity



Importantly, this distortion may have contributed to US monetary policy hitting the zero lower bound earlier than it would otherwise have done (if at all), adding to the need for US monetary policy to resort to "unconventional" measures (i.e. QE). This reinforced the global hunt for yield, resulting in spillovers on both developed and developing countries. Indeed, as the US dollar weakened in the aftermath of the crisis, the other developed economies saw a sharp appreciation of their currencies, both against the US dollar and against the Chinese currency (due to the exchange rate peg) than would otherwise have been the case. This required their monetary policies to work harder as well (or to accept slower recovery as was arguably the case in the euro area), again adding to the hunt for yield.

By managing both capital flows and the exchange rate while aiming for an independent monetary policy, China is trying to overcome the Trilemma and get a bit of everything. The distortion in the global financial system that this 'constrained adjustment' of the exchange rate causes is not so much that China is capturing a larger share of global exports and economic growth at the detriment of the United States, as argued e.g. by Blanchard and Milesi-Ferretti (2011). Rather, the nature of the distortion is that by managing capital movements and the exchange rate vis-à-vis the US dollar, China pushes monetary policies in the US and elsewhere to levels of accommodation where macroeconomic stabilization is achieved at a higher (if not a too high) risk of financial instability. In short, by managing capital flows as well as the exchange rate China not only 'constrains' the adjustments through the exchange rate channel, but also through the global financial markets channel (Chen and others, 2014), so contributing to cross-border spillovers.

As US monetary policy is now moving back to normal, how will the dynamics between the macroeconomic frameworks of the United States and that of China develop? When China nominally moved to a more flexible exchange rate in 2010 – and then again in 2014 – and was less reliant on foreign exchange intervention, it resorted to a 'selective' approach to capital controls to shield its economy from the tides of international capital flows – with occasional tolerance for large outflows in order to maintain the peg when the renminbi came under upward pressure against the US dollar. As China needs to keep a floor under the renminbi it recently resorted to large interventions in exchange markets when the renminbi came under downward pressure. In this case, like in the post-crisis years, China's intervention works against US monetary policy, with the interest rates increasing more than the Fed deems necessary initially.

In the next section we expand our earlier analysis and look at the same interactions, but now in the context of a full business cycle in the United States, encompassing both the contraction and expansion stages. In Part 2 we look at the empirical evidence on US monetary policy generating cycles in financial instability across the global (the "global financial cycle") and in Part 3 we assess how international policy coordination could help mitigate this cycle.

Part 2: US monetary policy and global financial stability

On 26 September this year the FOMC raised interest rates 25bps, the eighth such rate increase since the "liftoff" in interest rates in December 2015 by a total of 200 bps to a target range of 2%-2.25%. Since

October 2014 the Fed stopped making large-scale asset purchase while reinvesting principal payments, keeping its holdings of securities unchanged at US$ 4.2 trillion (23.4% of GDP).

The Fed chair Jay Powell has reiterated that interest rate hikes will be steady and gradual, with four rate hikes per year, 25 bps each, every March, June, September and December. It is only since September 2017 the Fed has started to unwind debt securities on its balance sheet. The Fed reiterated clearly that balance sheet normalization would be based on ceasing reinvestment of principal rather than directly selling securities in the market.

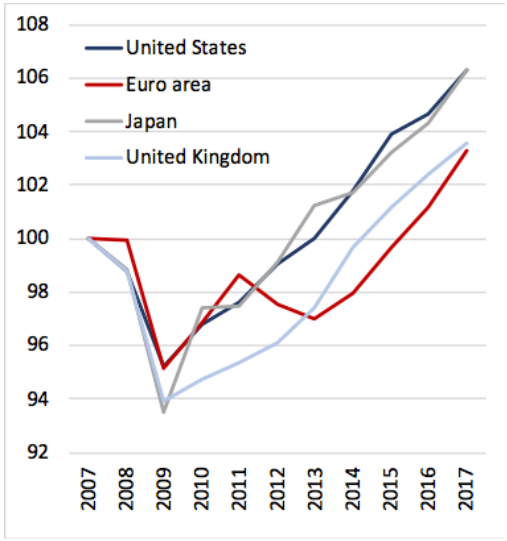
Against this backdrop we will look at the potential for this, supposedly 'gradual', normalization of US monetary policy and its spillover effects that risk generating disruptive financial instability further down the road and across the globe. We examine the main transmission channels, the timing and extent of financial stability implications and the many uncertainties surrounding these assessments. We will focus mostly on US rate hikes but note that some observers see a large role also for Fed balance sheet normalization, as noted above.

2a. The transmission channels

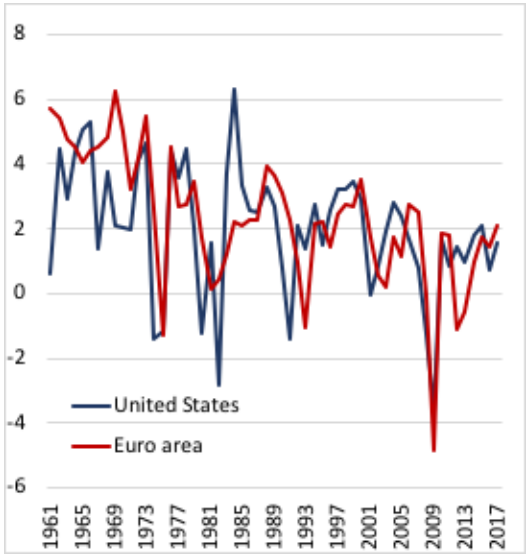
Among the systemically important developed economies, the US business cycle is the most advanced, and this is also reflected in their comparative stances of monetary policy. Chart 2.1, Panel A, shows that economic activity notably in Europe has recovered much less than in the United States from the 2009 recession. In the euro area this is due to the sovereign debt crisis that hit the economy in 2010-2013. As shown in Chart 2.1, Panel B, the euro area historically lagged the US economy by about a year, but this pattern has been disrupted in 2009 (see e.g. ECB, 2011) and at present the gap is exceptionally wide.

Chart 2.1: The business cycle in developed economies

A. Real per capita GDP in major developed economies (2007=100)



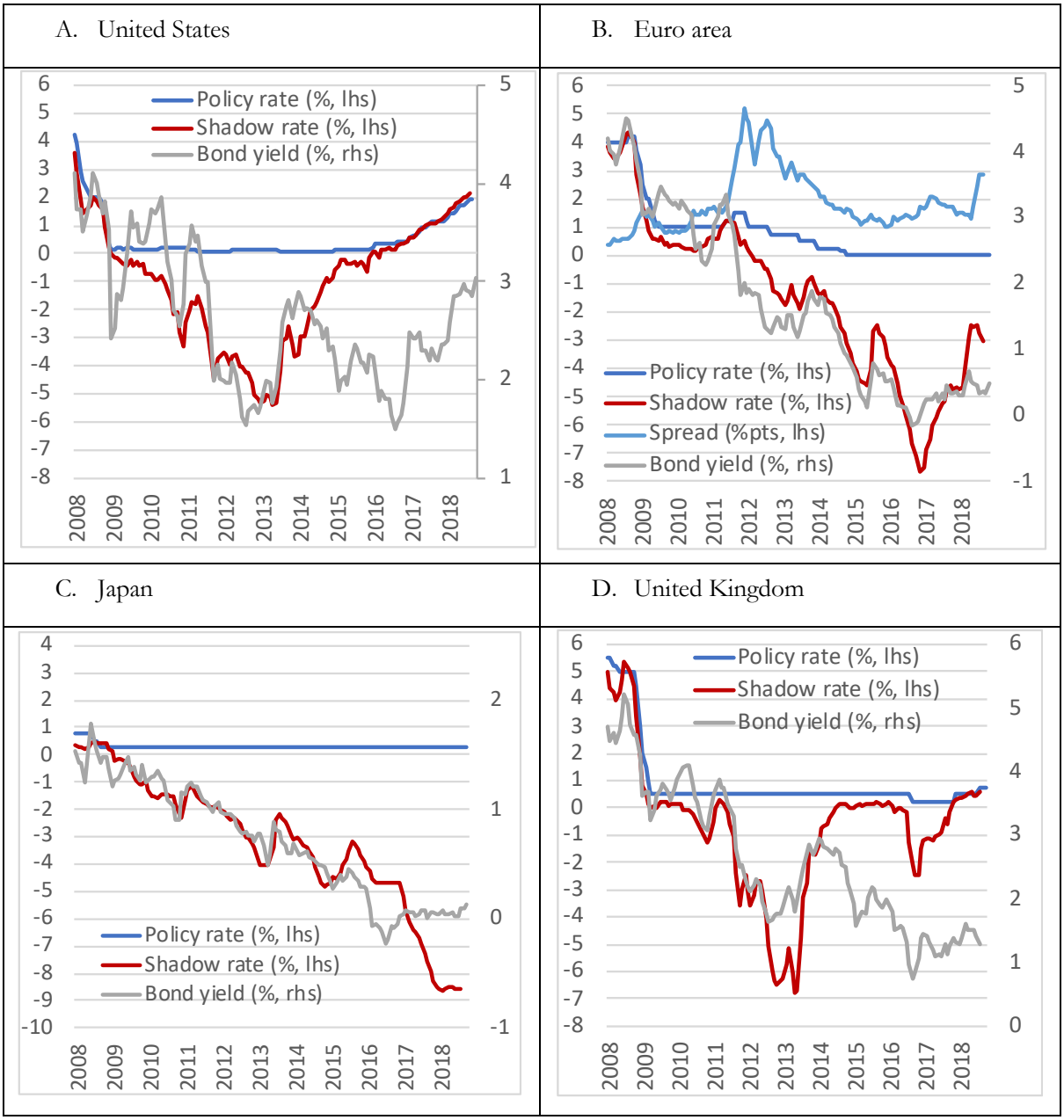
B. Real per capita GDP growth in the United States and euro area (%)



Source: World Bank.

Chart 2.2 shows that the stance of US monetary policy is, in fact, considerably tighter than reflected in the policy rate. Incorporating the impact of the (gradual) unwinding of the Federal Reserve's balance sheet, the 'shadow' policy interest rate shows a much more pronounced increase than the policy rate as such. According to these estimates (see also Société Générale 2018, Rickards 2018) the balance sheet normalization achieved so far would be a multiple of the rate hike of 3 percentage points, though Fed officials we spoke to consider this estimate way too high. It is somewhat puzzling that this – unlike in the 'taper tantrum' episode in 2013 – has so far not led to a much stronger increase in bond yields.

Chart 2.2: Monetary policy in developed economies



Note: Bond yield is for the benchmark 10-year government bonds (Bunds in the case of the euro area). The shadow policy rate incorporates the impact of variations in the central bank's balance sheet when the policy rate is at the zero lower bound as computed by the Reserve Bank of New Zealand, using the methodology of Wu and Xia (2016). "Spread" in Panel B refers to yield spread between Italian and German benchmark bonds (10Y BTP vs 10Y Bunds).
Sources: Reserve Bank of New Zealand, ECB, Federal Reserve, Bank of Japan and Bank of England.

If the world's main reserve currency issuer tightens monetary policy relative to the rest of the world, it necessarily has global implications. There are at least five spillover mechanisms:

1. As US rates rise, the United States will attract capital inflows, leading the dollar to appreciate against f other developed and emerging market economies. This yields competitiveness gains and an associated boost to net exports-driven economic growth in those economies. This is especially welcome for those developed economies that in the aftermath of the Great Financial Crisis still have significant slack – such as the euro area or Japan (see for instance Cova et al 2017, Bernoth and Koenig 2016).

2. China is likely to be an important exception as it still effectively pegs its currency to the US dollar (see Part 1). China is potentially exposed to capital flight in the face US monetary policy tightening. Although China employs macro-prudential policy so as to preserve financial stability, the Chinese monetary authorities will be desperate to prevent capital outflows and concomitant currency depreciation – given that capital outflows can starve the domestic banking sector of capital. The corollary is that the competitiveness gains China could benefit from through depreciation of the renminbi are traded against the risk of domestic financial instability.
3. Other emerging market economies, especially those that rely on US-dollar denominated credit, will likely resist currency depreciation against the US dollar as well. If they possess sufficient foreign exchange reserves they could do so through intervention, but otherwise they would have to tighten monetary policy at home so as to stem the outflow of capital. So they face a difficult trade-off between exchange rate depreciation and domestic monetary restraint, both of which entail financial stability risk.
4. The tightening of monetary policy in the US is likely to have financial stability implications in the United States itself. Leveraged buy-outs financed by cheap credit have been a major driver of the US stock market since the onset of the financial crisis. A major correction in the stock market – paling the one we have observed early this year – could trigger a risk-off that is likely to spill over to the rest of the globe.
5. A risk-off environment thus created could trigger capital flows to safe havens, including e.g. Japan, the euro area (in particular Germany) and – paradoxically – the United States itself. These will potentially depress emerging market currencies even further, notably in those emerging market economies that run substantial current account deficits, depend on US-dollar denominated credit and/or possess only limited foreign exchange reserves – Argentina and Turkey being prime examples. The United Kingdom may soon be in the same league as well in case of a disorderly Brexit, as may be Italy, being at the brink of political and/or financial collapse (see the recent spike in the BTP-Bund spread in Chart 2.1, Panel B).

These mechanisms are well-known, but we think there is an additional channel not explored as far as we know. Specifically, the structural features of the international monetary system, including the 'fear to float' in emerging market economies (Kliatskova and Mikkelsen, 2015) and the quasi-fixed exchange rate regime of China -- with a large trade surplus and a need for intervention in order to keep the exchange rate aligned with the Chinese leadership's policy objectives (see Part 1) -- has required the United States to ease monetary policy more than it otherwise would have. As a result, the world has ended up with higher levels of debt and interest rate risk – and hence potentially more financial instability – now that the US-monetary policy cycle turns. If it can be shown that this has been a repetitive pattern also in past cycles, it might help explain why global indebtedness has been trending up, contributing to a growing amplitude of the financial cycle. This would suggest that the next global financial crisis might be even more disruptive than the previous one.

2.b Prima facie evidence

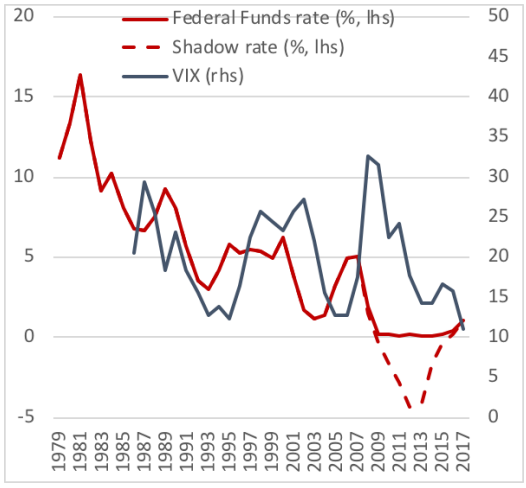
Do we have a case? Has policy normalization in the United States indeed produced financial instability in the past, and has this become worse with growing global indebtedness?

Eyeballing Chart 2.3 the following stylized facts emerge:

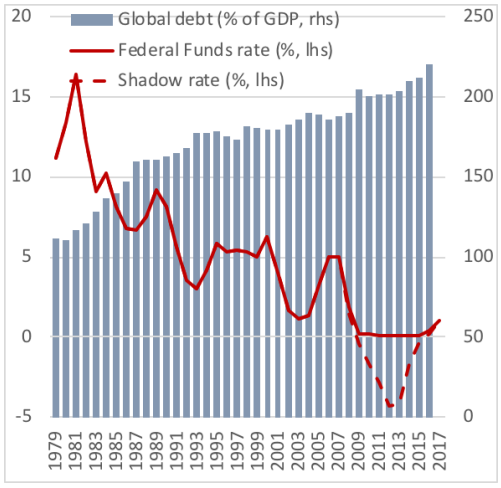
1. There is indeed evidence of a positive correlation between movements in the federal funds rate and at least one gauge of financial instability, the VIX. The former appears to lead the latter by about two years (see Panel A). This conclusion remains broadly valid if we apply the 'shadow rate' referred to in the previous sub-section, although we have yet to see an increase in financial instability following the increase in the shadow rate in recent years.
2. The sensitivity of the VIX to US monetary policy appears to have become stronger over time. For instance, in the second half of the 1990s and early 2000s (when the Mexican-peso, Asian, Ruble, and Dotcom crises hit) the VIX spiked more than in previous episodes of monetary policy tightening. Again, in the Great Financial Crisis of 2008-2009 the spike was more prominent than the previous one.

Chart 2.3: US monetary policy, global indebtedness and global financial stability

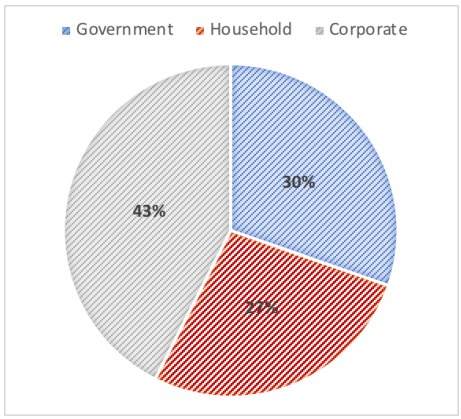
A. Federal Funds rate and stock market volatility



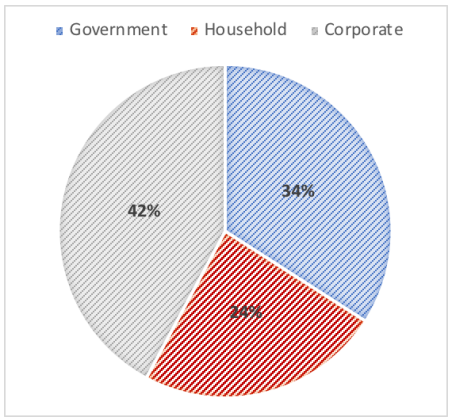
B. Federal Funds rate and global debt



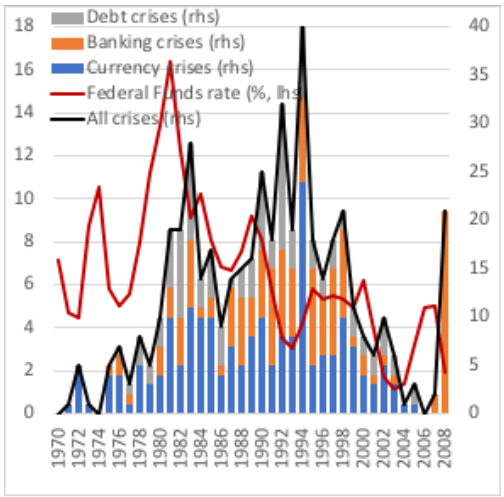
C. Global debt by sector (% of total, 2008)



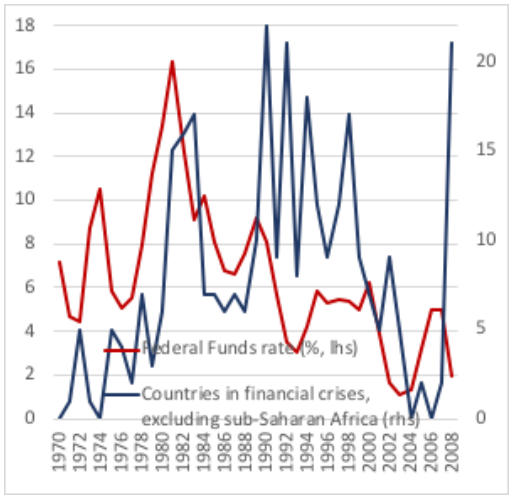
D. Global debt by sector (% of total, 2017)



E. Federal Funds rate and number of countries in financial crisis



F. Federal Funds rate and countries in financial crisis (sub-sample)



Sources: IMF (2017), Laeven and Valencia (2018), St Louis Fed., IMF Debt Database, BIS

3. Growing concerns over increasing leverage positions and global financial integration may be one factor explaining this tendency of financial crises to become more disruptive over time. High and increasing global debt (Panel B) is one indication of these tendencies. Global debt as such need not be an issue; rather would be high leverage, maturity mismatches and a tendency of more reckless risk taking with the secular decline in interest rates (which in turn may be a response to growing financial instability). But we do consider high global debt to be a reasonable proxy of global financial vulnerability.
4. At least one conventional alternative indicator of global financial instability -- the number of countries in financial crisis – also seems to be positively correlated with the stance of US monetary policy (Panel C). This correlation appears to be weaker. However, removing the large number of crises in non-systemic (mostly African) countries from the sample yields a stronger correlation, and again points to a growing financial vulnerability to US monetary policy.

While we see a causal effect running from US monetary policy to financial instability, obviously financial instability can have many other triggers, including poorly sequenced financial liberalization or supply shocks (Claessens and Kose, 2013). In principle it is possible empirically to disentangle the effects on monetary policy and other factors on financial instability, see for instance Goldberg and Krogstrup (2018).

In Annex A we develop a regression model based on the data in Chart 2.3 which broadly supports the above findings. We estimate the following equations:

$$V = \overset{+\,+}{V}(r, D), \frac{\partial V}{\partial r} = \overset{+}{f}(D) \tag{2.1}$$

$$D = \overset{+\,-}{D}(t, r) \tag{2.2}$$

The first equation assumes that global financial instability V, gauged by the volatility index VIX, is positively correlated with the federal funds rate r and the level of global debt D by way of a proxy of financial vulnerability (the signs of the impact are indicated above the variables). In addition, we expect the impact of variations of the federal funds rate on global financial stability to be stronger if global debt is higher (the relationship is non-linear). The second equation captures the impact of variations in the federal funds rate on global indebtedness – via its impact on global liquidity, risk taking and international capital flows. We do not expect US monetary policy to be the only driver of global debt, so we control for other drivers via the inclusion of an autonomous time trend (t).

To remove serial correlation of the residuals, we estimate the first equation as an error-correction model in levels and the second equation as an error correction model in first differences, which yields (t-statistics in brackets):

$$\Delta V = \underset{(-1.9)}{-33.1} - \underset{(-5.4)}{0.60}V_{-1} + \underset{(2.3)}{0.20}D_{-2} - \underset{(-3.6)}{10.6}r_{-2} + \underset{(4.4)}{0.07}(D_{-2}.r_{-2}), \bar{R}^2 = 0.62, DW = 2.2 \quad Sample: 1991-2017 \tag{2.3}$$

$$\Delta^2 D = \underset{(2.9)}{7.7} - \underset{(-7.6)}{1.37}\Delta D_{-1} - \underset{(-3.8)}{2.3}\Delta r_{-1} - \underset{(-2.1)}{0.27}V_{-2}, \bar{R}^2 = 0.73, DW = 2.3 \quad Sample: 1992-2016 \tag{2.4}$$

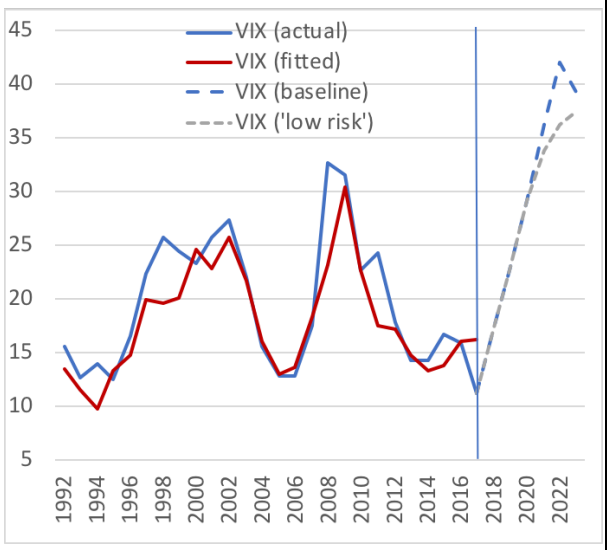
Annex A discusses in more detail the statistical properties and economic interpretation of the results. For now it suffices to mention that: (*i*) this simple model pretty well replicates the stylized developments depicted in Chart 2.3, (*ii*) the non-linearity mentioned above, with variations in the federal funds rate having a stronger impact on financial instability as global debt increases, is statistically significant, and (*iii*) the secular fall in the federal funds rate in past decades may well have been one of the drivers of the increase in global indebtedness.

Though not reported here, the statistical significance of the shadow rate, when included in these regressions *in lieu* of the actual federal funds rate, turns out to be considerably lower. This suggests that – while it may well have supported the economic recovery -- quantitative easing has had little impact on financial instability so far. However, the number of observations for which the federal funds rate has been at the

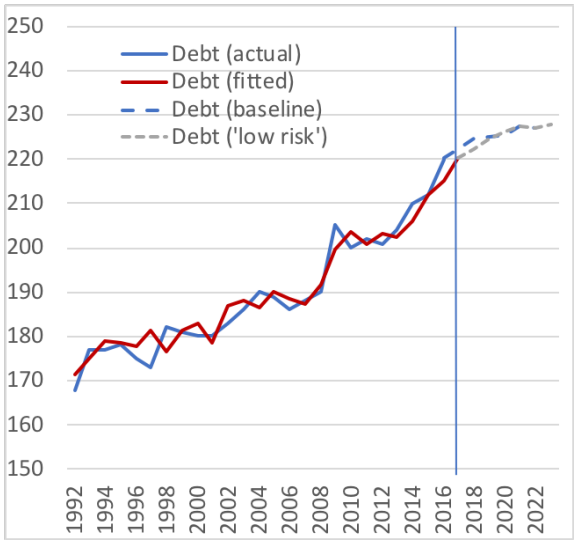
zero lower bound and the shadow rate departs from the actual federal funds rate is small, so the jury is still out. In any case, we will ignore the shadow rate from here on and focus on the actual federal funds rate. This should matter little insofar as the gap between the shadow rate and the federal funds rate has evaporated.

Chart 2.4: Model-based projections of financial instability

A. Projections for stock market volatility, 2018-2023



B. Projections for global debt, 2018-2023



Note: Federal funds rate in baseline averages 1.75%, 2.5%, 3%, 2% and 0% in the years 2018 until 2023, respectively. In the 'low risk' projection it averages 1.75%, 2%, 2%, 2%, 1% and 0%.

In Chart 2.4 we present a baseline projection for global debt and financial instability for the period 2018-2023 using this model for a given time path of the federal funds rate. We assume the federal funds rate to average 1¾ % in 2018, 2½ % in 2019 and 3% in 2020. As financial instability kicks in as a result, we assume the rate to drop to an average 2% in 2021, 1% in 2022 and back to nil in 2022. Financial instability, as gauged by the VIX, is projected to reach its highest level since 2009 by 2019 and to peak at an all-time high in 2021. These outcomes are relatively robust to changes in the assumed profile for the federal funds rate, given that about two-thirds of the projected increase has already occurred. Specifically, if we assume the federal funds rate to level off at 2 % in 2019-2021 and then to resume its baseline time path, the VIX would by 2021 still match its 2009 peak.

These projections would thus suggest that another financial crisis is in store as a result of the tightening of monetary policy in the United States, and that this crisis would be more disruptive than its predecessor. These projections, however, by their nature do not tell us what shape this crisis would take, where the epicenter would be, which counties or sectors would be hit hardest, etc.. To lend credibility to these projections evidence most be provided also on that score. A lot of research is available to point at possible vulnerabilities, but the evidence is not always convincing. So, might we be wrong and will yet another (and worse) financial crisis fail to materialize?

2.c Will this time be different?

The views as to whether another, if not worse, global financial crisis will occur in the wake of monetary policy normalization, greatly diverge.

In 2015 the World Economic Forum warned that since all major economies have higher levels of debt relative to GDP than they did at the eve of the crisis in 2007, the risks to financial stability have increased (Bruegel 2015, Dobbs et al 2015). These concerns have been echoed in official warnings by the IMF (2017), the World Bank (2018) and the BIS (Sobrun and Turner 2015). Monetary policy tightening could well be the trigger of financial instability, given that maturity mismatches have grown again (Park and Tian 2017, Paul 2018). Some forms of maturity transformation that have become popular are particularly

dangerous, such as share buybacks and carry trades financed by short-run debt (Acharya and Plantin 2017, Elgouam and Zago 2018).

Others believe that emerging market economies will manage to avoid systemic financial crisis because vulnerabilities, like fiscal and current account imbalances, have diminished overall in response to the Great Financial Crisis and because US monetary policy will be able to pre-empt the risk of global financial instability by slowing the pace and extent of monetary policy tightening (Coulibaly 2017, KPMG Economics 2017, Oliver 2017, Stevens 2017, Rong 2015, Sociéte Générale 2016). More in detail, according to these observers the risk of global financial stability will be contained because (we add some of our own reservations to each of these points):

1. The Fed's reluctance to 'go slow' has multiple rationales, including the large uncertainty over the degree of economic slack, an alleged drop in the 'natural rate' and international spillover effects (Berganza and Vales, 2016). They have also learned from the 'taper tantrum' episode, which showed that relatively small changes in portfolio flows can produce significant financial turmoil in emerging market economies (Dahhaus and Vasishta 2014, Burns 2014). All this is obviously true, but it also invites further debt growth. Hence it is not obvious that – on balance – a more modest path of rate hikes will achieve a lower risk of financial instability. And as we have highlighted above, substantial monetary tightening has occurred already and has yet to feed through.
2. Among the emerging market economies, the bulk of the increase in debt since the Great Financial Crisis has occurred in China, whose foreign debt and foreign-currency denominated debt is comparatively small, and who maintains a large positive net international investment position and massive official international reserves (see Chart 2.4). Moreover, insofar as the debt in developed economies has increased, the bulk of it occurred in Japan, and has mostly been domestically financed public debt (see again Chart 2.4). These are valid points but may well underestimate the possibility of debt burdens in these countries becoming unsustainable amid slower economic growth, necessitating bailouts which may come about only when systemic crisis is a fact and spilled over to the global financial system via risk-off sentiments. Given the sheer size of its economy, a debt scare in China would be particularly damaging for confidence.
3. There is a host of other arguments around which consider not so credible in light of past experience, including: (*i*) emerging market debt would be less of a concern because they have a higher growth potential (this did not prevent for instance the Asian crisis in the late1990s), (*ii*)debt-service burdens are still falling as past policy easing is still feeding through (which basically says that it may take a few years for a crisis to erupt which our own analysis indeed seems to confirm), (*iii*) the increase in debt has been matched by the increase in the value of the assets they finance (this is obviously misguided because once fire sales start this 'support' will quickly disappear), (*iv*) emerging market economies can draw down foreign reserves in response to currency depreciation pressure (true in some cases, but there are also major emerging market economies that are particularly vulnerable to a 'classic' currency crisis, see Chart 2.4), and (*v*) most external debt in foreign currency has been contracted by the commodities sector which is less vulnerable to foreign currency balance sheet mismatch as its revenues are denominated in foreign currency (but we would argue that signs domestic currency denomination puts the onus of exchange rate risk on foreign investors meaning that the risk of sudden stops would perhaps be even higher).

Chart 2.5 indeed suggests that vulnerabilities differ among countries as also stressed by Iacoviello and Navarro (2018), Caceres et al (2016) and Goés et al (2017). Specifically, from Chart 2.5 the following can be inferred:

1. Panels A and B confirm that while total debt continued to rise after the Great Financial Crisis, this was led by China, where debt surged from 180% to 260% of GDP, much of it in the burgeoning shadow banking sector which transforms large household savings into risky corporate debt. This is unlike the situation in the run-up to the crisis, when the bulk of global debt creation occurred in developed economies. Only Japan has seen large increases in debt in both periods, which is mostly public debt.
2. Panels C and D confirm that the external debt in foreign currency of emerging market economies has significantly increased over the last decade, supported by a low interest rates environment, their currencies appreciating, and rising commodity prices. However, foreign currency debt has

remained modest as a percentage of GDP and some have substantial foreign exchange reserves relative to their foreign debt. But some countries, like Argentina and Turkey, are vulnerable to exchange rate risk due to a comparatively high share of foreign exchange debt and comparatively small foreign exchange reserves. China is of course a class of its own, with comparatively small foreign debt dwarfed by huge foreign exchange reserves.

3. Panels E and F show that several large emerging market economies have remained net debtors to the rest of the world, though not China, Russia, South Africa and Saudi Arabia due to their persistent trade surpluses. Meanwhile, the United States remains by far the biggest debtor globally, with Japan, China and Germany by far the biggest creditors, reflecting the absence of exchange rate adjustment in the presence of large current account surpluses (in the case of Germany its external creditor position is mostly against the euro area's southern rim). Apart from the United States, developed economies broadly finance emerging market economies' current account deficits aside from China. Capital flows downhill as predicted by text books, except in the United States (and China where it moves the other way around.

Against this backdrop we see a number of risks some of the more benign assessments may be underestimating. Specifically, turmoil in weak emerging market countries on the back of higher US rates (Argentina, Turkey) could easily spread in a risk-off environment. Moreover, stock repurchase programs of US companies (relying on cheap credit), which have artificially boosted stock market returns, could go in reverse as monetary policy tightens.

Aside from these spill-over effects from monetary policy tightening in the United States, a number of other risk factors need to be considered. A trade war could take hold, depressing sentiment and compromising business investment plans both in advanced and emerging market economies. Also could it entail stagflation, adding yet another trade-off to monetary policy, which will have to choose between inflation control and stimulating activity. trade adversely affected, stagflation). Developments in the European Union are not comforting, with coherence threatened by the refugees problem and a conflict between Germany and Italy on fiscal leeway potentially undermining the single currency. And finally, government protection against default risk of the burgeoning Chinese shadow banking sector, that Chinese investors take for granted, may be tested someday. If all or some of these risk materialize in a context of tighter US monetary policy, a perfect storm may come.

Part 3 Is there scope for international coordination?

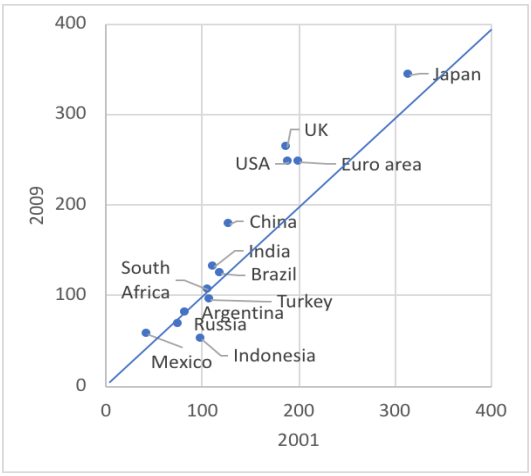
In previous essays we have argued that if certain conditions are met the international coordination of monetary policy may help to rein in the adverse spillover effects US monetary policy (Subacchi and Van den Noord, 2012 and 2016). Specifically, we argued that policy coordination is feasible when it is beneficial to all players. Monetary policies implemented by advanced economies in support of domestic output often generate spillovers for other countries which in turn could jeopardize financial instability. We concluded that the international coordination of monetary policies could help manage the trade-off, but only if countries share the same degree of exposure to financial instability and the same preferences regarding the welfare cost of financial instability relative to other macroeconomic objectives.

In this Part 3 we revisit these issues, building on the empirical findings in Part 2, notably the observation that the impact of the international spillovers tend to become more disruptive with each cycle as global indebtedness increases. We further develop the analytical tools used in our earlier essays, i.e. a set of simple (game-theoretic) models, which we calibrate numerically on available empirical estimates (including our own). Like in our earlier essays, we derive monetary policy reaction functions in the pursuit of macroeconomic and financial stability, but we introduce two novelties. One is to include an interaction between (endogenous) debt formation and the sensitivity of financial instability to monetary policy. The other novelty is that we distinguish two periods – mimicking a cyclical downswing and a cyclical upswing together constituting a full business cycle

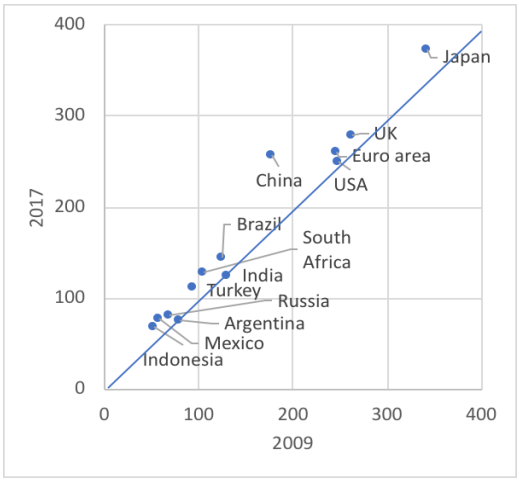
We first look at the tradeoff between macroeconomic and financial stability in a single developed economy, and subsequently analyze the interaction with (*i*) another developed economy, (*ii*) an emerging market economy with managed exchange rates/capital accounts and (*iii*) an emerging market economy with floating exchange rates/liberal capital accounts.

Chart 2.5: Global vulnerabilities

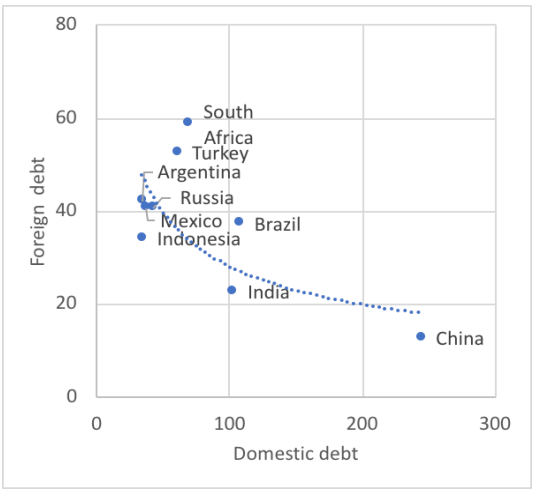
A. Debt ratio to GDP, 2001-2009 (%)



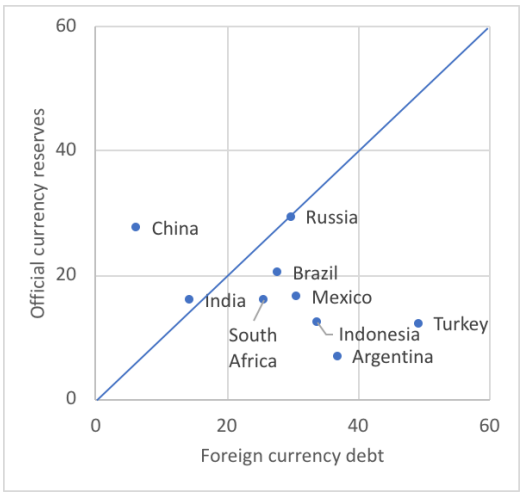
B. Debt ratio to GDP, 2009-2017 (%)



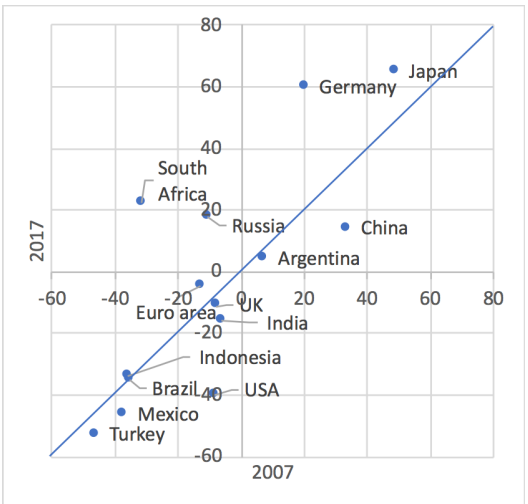
C. Domestic and foreign debt (2017, % of GDP)



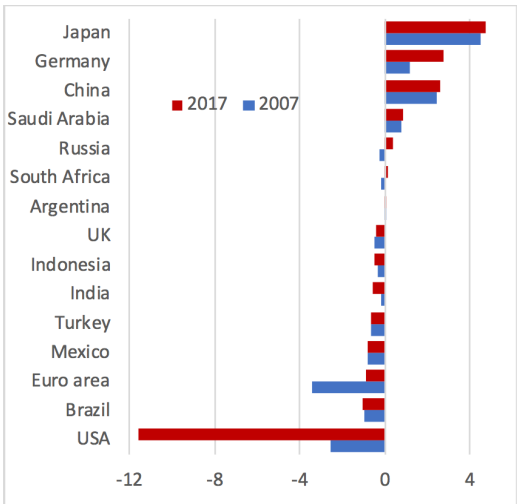
D. Foreign currency debt and official reserves (2017, % of GDP)



E. Net international investment position (% of GDP)



F. Net international investment position (% of global GDP)



Source: IMF

3.a The trade-off between macroeconomic and financial stability

In this section we put the spotlight on the inter-temporal choices the monetary authorities in any jurisdiction, and *a fortiori* the Fed, are grappling with. Specifically, any change in monetary policy today has ramifications for financial instability tomorrow via changes in asset prices, leverage positions and indebtedness. By the same token, the risk of financial instability today is rooted in monetary policy decisions yesterday. Notably BIS economists never tire to stress this point, see e.g. Borio (2014) and Juselius et al. (2016), and also Bauer and Granziera (2016).

In order to capture this intertemporal trade-off formally we set up a stylized model for a single economy and distinguish two periods, 0 and 1 (equivalent to the 'short run' and the 'medium run', respectively). All variables are expressed as (log-) deviations from an unspecified baseline. The gap between aggregate demand and aggregate supply y_t (the 'output gap') is perceived by the monetary authorities to be a negative function of the interest rate r_t plus an exogenous shock u_t (a version of the well-known IS-relationship):

(3.1) $$y_t = -\varphi r_t + u_t, t = 0,1$$

The way to interpret this equation is that it reflects the monetary authorities' assessment of the baseline relationship between monetary policy and economic activity. In addition, there may be risks surrounding this relationship due to financial instability, which we will treat separately (see below). For the sake of simplicity, we omit the Philips relationship, which links inflation to the output gap, without loss of generality if the two are always positively correlated (i.e. we abstract from supply shocks). We assume the economy to be in a slump initially ($u_0 < 0$), followed by a recovery or outright boom in the next period ($u_1 > u_0$or $u_1 > 0$). We will argue that the interest rates r_t the monetary authorities will choose not only depends on the evolution of the contemporaneous demand shock term u_t, and its repercussions on macroeconomic stability, but also on the financial stability implications of their choice.

We consider financial stability to refer to the stability of the financial system and its capacity to fulfil its basic functions of financial intermediation and payments, which is a broader concept than price stability which central banks normally have in their mandate. We see the development of financial risk premia (affecting the cost of borrowing) in response to monetary policy action to be a crucial determinant of financial stability, so we need to model this explicitly. Investor's behavior is reflected in the evolution of a multitude of financial indicators, such as leverage or asset prices, but we take the level of debt as our gauge. We assume debt to increase (relative to baseline) in response to monetary stimulus, which then risks becoming unsustainable when monetary policy is tightened.

We assume debt at the start of period 0, D_0, to be nil. This is inevitable to keep our model simple, though without invalidating any of the points we want to make. In any case, since we formulate the model in terms of deviations from a given baseline, which includes legacy debt, it is in fact not logically inconsistent to assume $D_0 = 0$. Debt at the start of period 1, D_1, then only consists of new debt formation in period 0. The latter is assumed to be a (negative) function of the interest rate in period 0, r_0, on the premise that cheap credit means more credit. Hence at the start of period 1, debt should equal:

(3.2) $$D_1 = -\delta r_0$$

We posit that financial instability in period 1, V_1, depends on the interest rate in period 1 r_1 and debt D_1. We assume this relationship to be non-linear, in the sense that it is the combination (or interaction) of interest rates and debt that determines the risk of financial instability (see part 2 for the empirical evidence):

(3.3) $$V_1 = \gamma r_1 D_1$$

The monetary authorities set the interest rate in both periods so as to minimize the welfare loss stemming from variations in the output gap as well as from financial instability:

(3.4) $$\min_{r_0, r_1} L = \frac{1}{2} y_0^2 + \beta \left(\frac{1}{2} y_1^2 + \alpha V_1 \right), \alpha \geq 0, 0 \leq \beta \leq 1$$

In this welfare-loss function α is the relative weight of financial instability vs macroeconomic stability, and β is the time discount factor ($\beta = 0$ if the monetary authorities are perfectly myopic). We will assume that the monetary authorities pre-commit to the interest rates for periods 0 and 1. However, since

monetary policy in this set-up is conditional on the expected shocks u_t materializing, it is akin to 'forward guidance' more than to a hard commitment.

Solving the minimization problem yields:

$$(3.5) \quad \begin{cases} r_0 = \frac{1}{\varphi\Delta}\left[u_0 + \beta\frac{\alpha\gamma\delta}{\varphi^2}u_1\right] \\ r_1 = \frac{1}{\varphi\Delta}\left[u_1 + \frac{\alpha\gamma\delta}{\varphi^2}u_0\right] \end{cases}$$

where $\Delta = 1 - \beta\left(\frac{\alpha\gamma\delta}{\varphi^2}\right)^2$.

This result gives rise to the following observations:

1. A projected cyclical upswing in period 1 ($u_1 > 0$) commands higher interest rates not only in period 1, but also in the preceding period 0. This is to prevent too much debt building up, as this would be costly in terms of its financial stability implications.
2. Similarly, a slump in period 0 ($u_0 < 0$), drags down interest rates not only in period 0, but also in period 1 to offset the financial stability risk entailed by easy money (and strong debt accumulation) in period 0.
3. If the monetary authorities do not care about financial stability or intend to rely on other instruments to contain it ($\alpha = 0$), the interest rate profile solely reflects the business cycle, i.e. the evolution of the demand shock term u_t.
4. If the central bank is perfectly myopic ($\beta = 0$), monetary policy in period 0 is exclusively driven by the contemporaneous cyclical position of the economy ($u_0 < 0$). However, in period 1 monetary policy is still partly driven by the cyclical position in period 0, via its impact on monetary policy stimulus and debt growth in period 0.
5. Even if we assume the business cycle to be perfectly symmetric ($u_0 + u_1 = 0, u_0 < 0$), the interest rate profile is not symmetric as the rate tends to fall relative to neutral level, i.e. $r_0 + r_1 < 0$if $0<\beta < 1$.

We think these are important observations. The corollary of the last point is that if the average interest rate over the cycle becomes the 'new neutral' for the next cycle and again is undershot, and so on thereafter, the 'neutral rate' would tend to drift down and debt tend to drift up. This would provide an alternative explanation for the symptoms of 'secular stagnation', i.e. rising debt and falling interest rates from one cycle to the next, without actually assuming secular stagnation (secular stagnation would imply that $u_0 + u_1 < 0$, whereas we assume that $u_0 + u_1 = 0$).

The first four points illustrate that there is reason for monetary authorities to refrain from 'excessive' easing of monetary policy in the slump so as to pre-empt financial stability risk once monetary policy is tightened in the subsequent upswing. This concern is oft expressed by the IMF (2017), the BIS (see above) and 'conservative' scholars in Europe (e.g. Beck and Wieland, 2017). If such warnings are not heeded, these dynamics could lead to a 'financial dominance trap' (Turner, 2014), in which the substantial accumulation of debt and the associated interest rate risk confront monetary policymakers with ever more difficult dilemmas.

Whatever one's judgment is as to whether monetary policy ease in the wake of the Great Financial Crisis has been or has not been 'excessive', few would disagree that there is a trade-off between short-run macroeconomic stabilization and medium-run financial stability, as illustrated by our stylized model. Disturbingly, as we will see below, the present international monetary system generates forces which complicate this trade-off, potentially leading to a too fast build-up of debt and growing vulnerabilities in the face monetary policy normalization. We turn to this in the next sections.

3.b The interaction between developed economies

After the demise of Bretton Woods in the early 1970s initially the role of the US dollar as the main global currency for international trade and reserves was questioned, but the supply of US dollars remained the

main source of global liquidity and the supply of US treasury bonds the main source of risk-free financial assets. The liberalization of capital movements and financial deregulation throughout the 1980s and early 1990s again reinforced the US-dollar's role as the global currency. Hence, whenever US monetary policy was changed, this boosted global liquidity via the injection of US dollars into the system via the US trade deficit and capital exports, as well as via the creation of US-dollars offshore. US monetary policy thus had a powerful impact on exchange rates and, via the monetary policy reactions this triggered, interest rates in the developed world.

Here we examine if in such a world the coordination of monetary policies is feasible, by way of a benchmark for when we discuss the nexus with emerging market economies further below. To do this we develop a two-country version of our stylized model so as to gauge the international spillover effects of monetary policy. This is a standard Mundell-Fleming framework, in which the output (IS) equation includes the exchange rate e_t, and reads (an asterisk always denotes the 'foreign economy' as opposed to the 'home economy'):

$$(3.6) \qquad \begin{cases} y_t = -\varphi r_t - \omega e_t + u_t \\ y_t^* = -\varphi r_t^* - \omega e_t^* + u_t^* \end{cases}, t = 0,1$$

The exchange rate is a function of the yield spread of r_t against the foreign interest rate r_t^*:

$$(3.7) \qquad \begin{cases} e_t = \chi(r_t - r_t^*) \\ e_t^* = -e_t \end{cases}, t = 0,1$$

For simplicity we omit the direct trade channel (the impact of changes in domestic demand in one country spilling over to the other country via imports) as this is not central to our argument and will not alter our conclusions. As in the single-country case we also omit the Philips curve relationship on the assumption that inflation and the output gap are always positively correlated. We assume again that legacy debt at the start of period 0 in both countries, D_0 and D_0^*, is nil. Debt at the start of period 1, D_1 and D_1^*, is a (negative) function of the interest rate in period 0, r_0 and r_0^*, so:

$$(3.8) \qquad \begin{cases} D_1 = -\delta r_0 \\ D_1^* = -\delta r_0^* \end{cases}$$

This formulation implies that all debt is denominated in domestic currency and hence yields the domestic interest rate. But it does not rule out cross-country holding of debt and the associated capital inflows and outflows, though the exchange risk is assumed to fall on the creditor. The risk of financial instability in period 1 is again a (positive) function of the interaction (product) of the relevant interest rate r_1 and r_1^* and debt D_1 and D_1^*, respectively:

$$(3.9) \qquad \begin{cases} V_1 = \gamma r_1 D_1 \\ V_1^* = \gamma r_1^* D_1^* \end{cases}$$

We assume that the monetary authorities in both jurisdictions minimize the welfare loss stemming from macroeconomic instability (excess demand or supply and the associated risk of inflation or deflation) and financial instability:

$$(3.10) \qquad \begin{cases} \min\limits_{r_0, r_1} L = \frac{1}{2} y_0^2 + \beta \left(\frac{1}{2} y_1^2 + \alpha_1 V_1 + \alpha_2 V_1^* \right) \\ \min\limits_{r_0^*, r_1^*} L^* = \frac{1}{2} y_0^{*2} + \beta \left(\frac{1}{2} y_1^{*2} + \alpha_1 V_1^* + \alpha_2 V_1 \right) \end{cases}$$

Financial instability in each country is assumed to spill over to the other country via confidence (Contagion) effects and the overall risk sentiment – so there are externalities in both directions. With externalities there would be scope for welfare-enhancing coordination of monetary policies, to which we will turn later.

In Annex B the Nash solution of this problem is derived. A shown in the annex this solution yields four policy reactions functions, one for each country and for each period, which in short-hand notation read (signs of first derivatives are indicated above the variable):

$$(3.11) \qquad \overset{+\ +\ +\ +}{r_0 = r_0(r_0^*, r_1^*, u_0, u_1)}$$

$$r_1 = r_1(r_0^*, r_1^*, u_0, u_1) \quad (3.12)$$

$$r_0^* = r_0^*(r_0, r_1, u_0^*, u_1^*) \quad (3.13)$$

$$r_1^* = r_1^*(r_0, r_1, u_0^*, u_1^*) \quad (3.14)$$

Like in our one-country model monetary policy in period 0 responds to demand shocks in both periods, and the same for monetary policy in period 1. This implies interest rate smoothing, so as to limit the debt build-up in period 0. As shown in the annex, the extent of interest rate smoothing again depends on the time discount factor β. In addition, monetary policy in each economy responds to monetary policy abroad, due to its impact on economic activity via the exchange rate. As shown in the annex, this cross-country dependency of monetary policy will be stronger if the sensitivity of financial instability to debt and interest rate changes is larger.

To calibrate the parameters of the model we proceed as follows. First, we adopt numerical values for the structural parameters in the IS and exchange rate equations. Specifically,

1. We derive the output response multipliers of changes the interest rate (φ), and the exchange rate (ω) from the OECD's global macroeconomic model (Hervé et al. 2010), which yields approximately $\varphi = 1$ and $\omega = 0.2$. These multipliers apply to the United States, but to preserve symmetry we will apply these to both economies.
2. The semi-elasticity of the US-dollar exchange rate with respect to the yield spread is fixed at $\chi = 7.5$, taking the simple average of recent estimates by Gerlach (2018) for the dollar exchange rate against the euro (around 10) and by Curcuru (2017) for a range of developed economies' exchange rates (around 5).
3. The responsiveness of financial instability to the interest rate and debt, γ, and of debt formation to the interest rate, δ, are loosely based on the regression results reported in Annex 2, which yields $\gamma = 1$ and $\delta = 2$. We fix the discount factor at $\beta = 0.9$ and attach equal weights to macroeconomic stability and financial stability (both at home and abroad) such that $\alpha_1 = \alpha_2 = 0.1$ (given that our gauge of financial stability, the VIX, is an order of magnitude of ten times the variation in the output gap).

In Table 3.1 we report the Nash solution for a case in which the 'home economy' is subject to a series of demand shocks $u_0 = -5\%$ and $u_1 = 5\%$, i.e. an economic downswing followed by an upswing of equal magnitude. For simplicity the 'foreign economy' is assumed not to be exposed to domestic demand shocks, only to spillovers (and multiplier effects) from demand shocks in the 'home economy'.

The most notable result is that in both economies indebtedness increases over the cycle and that both economies are hit by financial instability in the upswing phase when monetary policy is tightened. Since the 'home economy' is assumed to be the epicentre of the demand shocks, those movements are more pronounced there than in the 'foreign economy'. Even so, a notable feature of this exercise is that the 'foreign economy' not only carries part of the burden of macroeconomic adjustment (slack in period 0 followed by overheating in period 1), but is also exposed to spillovers of financial instability in the 'home economy'. As a result, the welfare losses in both economies turn out to be similar.

Can these welfare losses be contained by international policy coordination? According to the cooperative solution also reported in Table 3.1, the answer is yes. We define cooperation to involve the conduct of monetary policy in each economy to pursue the reduction of global financial instability, that is both at home and abroad, alongside macroeconomic stability at home. Hence, we assume this cooperation to refer only to financial stability while the monetary authorities in each economy stick to their mandate to minimize macroeconomic instability at home. We think this formulation of (partial) cooperation does better justice to the principle that central banks are primarily accountable to their domestic constituencies and that any deviation from this principle would be politically acceptable only to the extent that it would help to prevent unintended spillover effects. The relevant welfare loss functions now read:

Table 3.1: International spillover effects -- two developed economies

	Nash				Coordination			
Economy	'Home'		'Other'		'Home'		'Other'	
Period	0	1	0	1	0	1	0	1
Output	-0.2	0.2	-0.1	0.1	-0.4	0.4	-0.2	0.3
Interest rate	-2.9	2.9	-1.7	1.7	-2.8	2.8	-1.6	1.5
Exchange rate	-9.2	9.2	9.2	-9.2	-9.1	9.0	9.1	-9.1
Debt		5.9		3.4		5.6		3.2
Financial instability		17.2		5.8		15.4		4.9
Welfare loss	2.1		2.1		2.0		1.9	

Note: all variables in (%-point) deviations from baseline

$$(3.15)\quad \begin{cases} \min\limits_{r_0,r_1} L = \frac{1}{2}y_0^2 + \beta\left[\frac{1}{2}y_1^2 + (\alpha_1+\alpha_2)(V_1+V_1^*)\right] \\ \min\limits_{r_0^*,r_1^*} L^* = \frac{1}{2}y_0^{*2} + \beta\left[\frac{1}{2}y_1^{*2} + (\alpha_1+\alpha_2)(V_1+V_1^*)\right] \end{cases}$$

The associated policy reaction functions are derived in the Annex. As reported in Table 3.1, in comparison with the Nash solution the time profile of the interest rates over the cycle are smoother and the yield spreads between the economies narrower. As a result of the latter, the exchange rate movements are also smoother. Importantly, the levels of indebtedness in both economies are lower and the welfare losses smaller. Apparently, coordination of monetary policies is Pareto-optimal.

One issue we want to highlight is what would happen if the 'other' economy happens to be a monetary union. The European Economic and Monetary Union (EMU) involves a single currency and single monetary policy, so for our purposes it is not different from any developed economy, and all of the above conclusions apply. However, in the vast literature on EMU its hallmark is the different proneness to unsustainable accumulation of (private or public) debt across the sovereign jurisdictions that constitute the monetary union. Specifically, it is usually assumed that EMU contains 'thrifty' and 'profligate' members of the monetary union, such as Germany and Italy, respectively.

If we adopt this dichotomy in our stylized two-country framework, debt at the start of period 1 in the 'thrifty' and 'profligate' members are, respectively, $D_1^{*'}$, $D_1^{*''}$. Both are a (negative) function of the single interest rate in period 0, r_0^*. However, the propensity of debt formation is comparatively low in the 'thrifty' member and comparatively high in the 'profligate' member, such that:

$$(3.16)\quad \begin{cases} D_1^{*\prime} = -\delta^{*'} r_0^* \\ D_1^{*\prime\prime} = -\delta^{*\prime\prime} r_0^*, \delta^{*\prime\prime} > \delta^{*\prime}, \delta = \frac{1}{2}\delta^{*\prime} + \frac{1}{2}\delta^{*\prime\prime} \end{cases}$$

This formulation implies that in a period with monetary stimulus ($r_0^* < 0$) debt will accumulate faster in the 'profligate' jurisdiction than in the 'thrifty' jurisdiction, although on average debt in the monetary union as a whole responds the same way as in our original two-country model. In turn financial instability in each jurisdiction is a (positive) function of the single interest rate r_1^* and debt $D_1^{*'}$ and $D_1^{*''}$:

$$(3.17)\quad \begin{cases} V_1^* = \frac{1}{2}V_1^{*\prime} + \frac{1}{2}V_1^{*\prime\prime} \\ V_1^{*\prime} = \gamma r_1^* D_1^{*\prime} \\ V_1^{*\prime\prime} = \gamma r_1^* D_1^{*\prime\prime} \end{cases}$$

In Table 3.2 we show the results in which the assumed values for the debt responsiveness parameters δ in the monetary union are $\delta^{*'} = 0$ and $\delta^{*''} = 2\delta$ while all other parameters of the model are unchanged. Because $\delta^{*''} > \delta^{*'}$ the onus of financial instability is on the 'profligate' jurisdiction, i.e. $V_1^{*''} > V_1^{*'}$. This may be reflected in for instance the bond yield spread between the 'profligate' and 'thrifty' jurisdictions, alongside other indicators of financial instability. However, as noted above, all results reported in Table 3.1 still apply and hence the scope for international coordination remains the same: coordination of monetary policies between the 'home economy' and the monetary union is Pareto-optimal. The crucial question though is if a monetary union in which its members systematically diverge in terms of their financial stability is (politically) viable. Obviously this is the rationale behind many coordination mechanisms developed in EMU (such as the 'Stability and Growth Pact'), but so far compliance has been disappointing in the absence of powerful enforcement.

Table 3.2: International spillover effects – monetary union

	Nash				Coordination			
Jurisdiction	'Thrifty'		'Profligate'		'Thrifty'		'Profligate'	
Period	0	1	0	1	0	1	0	1
Interest rate	-1.7	1.7	-1.7	1.7	-1.6	1.5	-1.6	1.5
Debt		0.0		6.9		0.0		6.3
Financial instability		0.0		11.7		0.0		9.8

Note: all variables in (%-point) deviations from baseline

3.c The nexus with emerging market economies

With the entry of emerging market economies as major players the international monetary system has changed fundamentally. Many of these economies adopted open capital accounts and *de jure* floating exchange rates, but soon discovered that this could give rise to vulnerabilities, as we discussed in part 2.

In view of this experience it is not so surprising that China opted to keep its capital account closed (or at least managed) and to peg its exchange rate against (predominantly) the US dollar, and as we will see this has important ramifications for the functioning of the international monetary system. We modify our model to assume the 'foreign economy' (again denoted by an asterisk) to be an emerging market economy which chooses to manage its exchange rate and capital account in the pursuit of exchange rate stability. In fact, all we need to do is to assume that $\chi = 0$, which according to equation (3.7) automatically implies that $e_t = 0$ (the exchange rate is fixed). As shown in Annex B, in Nash equilibrium the international interdependency of monetary policies now disappears from the reaction functions, which read:

$$r_0 = r_0(u_0, u_1) \quad (+\ +) \tag{3.18}$$

$$r_1 = r_1(u_0, u_1) \quad (+\ +) \tag{3.19}$$

$$r_0^* = r_0^*(u_0^*, u_1^*) \quad (+\ +) \tag{3.20}$$

$$r_1^* = r_1^*(u_0^*, u_1^*) \quad (+\ +) \tag{3.21}$$

Monetary policy in both economies is now perfectly independent, as if we are dealing with two closed economies. Because the exchange rate is fixed, monetary policy in one country does not affect the stance of monetary policy in the other economy. However, there are still financial instability spillovers as reflected in the welfare loss functions (3.10), on the assumption that the reverberations of a financial crisis in one economy will be felt also in the other economy via contagion. So potentially there could still be scope for international coordination.

Table 3.3: International spillover effects – a developed and an emerging market economy (with closed capital account and *de jure* fixed exchange rate)

	Nash				Coordination			
Economy	Developed		Emerging		Developed		Emerging	
Period	0	1	0	1	0	1	0	1
Output	-0.7	0.9	0.0	0.0	-1.3	1.5	0.0	0.0
Interest rate	-4.3	4.1	0.0	0.0	-3.7	3.5	0.0	0.0
Exchange rate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Debt		8.5		0.0		7.5		0.0
Financial instability		35.3		0.0		26.2		0.0
Welfare loss	3.8		3.2		4.2		2.4	

Note: all variables in (%-point) deviations from baseline

As reported in Table 3.3, however, while coordination of monetary policies results in a welfare gain for the emerging market economy – as it is benefitting from less financial instability in the developed economy – the developed market economy would suffer an additional welfare loss from international coordination. This is because the developed economy would be forced to accept a sub-optimal smoothing of its interest rate profile and debt formation without a benefit of smaller spillback of financial instability abroad. But, also without coordination, the developed economy is forced to conduct a more active monetary policy in both phases of the business cycle to offset the lack of support from the exchange rate adjustment, which results in a higher level of indebtedness than would otherwise materialize. As a result, the presence of a large systemically important emerging market economy with a fixed exchange rate and closed capital account is, despite its insulation from disruptive capital flows, a potential source of greater global financial instability.

We now turn to the case in which capital in the emerging market economy is completely footloose and the exchange rate (at least *de jure*) freely floating. In this case we may assume the elasticity of the exchange rate with respect to the yield spread to approach infinity, i.e. $\chi \to \infty$. According to equation (3.7) this means that there is effectively only one (global) interest rate as always $r_t - r_t^* = 0$. In that case it is not *a priori* clear which country sets monetary policy for the globe. Following Blanchard and Milesi-Ferretti (2011), we assume this to be the developed economy. However, unlike their model (which otherwise has a similar structure to ours), we do not assume the emerging market economy to be able to fix the exchange rate, which we assume to float freely.

In game-theoretic terms it is natural in that case to assume that the developed economy acts as a 'Stackleberg leader' who commits to an interest rate profile before the emerging market economy does, with the latter reacting to the developed economy's monetary policy (though in practice emerging market economies may have some room for monetary policy independence as elaborated further down below). In making its decision, the developed economy must anticipate how the emerging market economy reacts to that decision, otherwise there would be (time-) inconsistency. In Annex B we show that if $\chi \to \infty$ a Stackleberg equilibrium exists, from which the following policy reaction functions emerge:

$$r_0 = r_0(u_0, u_1) \quad (3.21)$$

$$r_1 = r_1(u_0, u_1) \quad (3.22)$$

$$\begin{cases} r_0^* = r_0 \\ r_1^* = r_1 \end{cases} \quad (3.23)$$

Hence the developed economy sets monetary policy only as a function of the domestic demand shocks it is exposed to over the cycle while the emerging market economy (the 'Stackleberg follower') simply adopts the same interest rates as the developed economy. This effectively seals off the exchange rate channel, it being *de facto* fixed regardless of the *de jure* free float. The corollary is that the emerging market economy is completely at the mercy of the monetary policy in the developed economy. This is obviously an extreme case and the reality may be less stark as some emerging market economies (beyond China) manage to a *de jure* pegged exchange rate, thus providing room for independent monetary policy.

Table 3.4: International spillover effects – a developed and an emerging market economy (open capital account and *de facto* fixed exchange rates)

	Stackleberg				Coordination			
Economy	Developed		Emerging		Developed		Emerging	
Period	0	1	0	1	0	1	0	1
Output	-1.3	1.5	3.7	-3.5	-1.7	2.6	3.3	-2.4
Interest rate	-3.7	3.5	-3.7	3.5	-3.3	2.4	-3.3	2.4
Exchange rate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Debt		7.5		7.5		6.6		6.6
Financial instability		26.2		26.2		15.6		15.6
Welfare loss	6.5		17.2		7.4		10.8	

Note: all variables in (%-point) deviations from baseline

Table 3.4 reports the numerical solutions for the Stackleberg and cooperative equilibria. In Stackleberg equilibrium the two economies behave perfectly counter-cyclical, with the emerging market booming when the developed economy is in a slump and the former contracting when the latter recovers. Because in both economies interest rates are the same, their debt profile is also the same and both are subject to the same level of financial instability. However, the welfare loss is bigger for the emerging market economy because – on top financial instability – it is also subject to its monetary policy being out of whack with its domestic macroeconomic stabilization needs. International coordination mitigates these effects, but, while welfare enhancing for the emerging market economy, is welfare diminishing for the developed economy. Therefore, it is hard to see how international co-ordination could be agreed to or sustained.

Also, if we assume the exchange rate regime and monetary policy responses among emerging market economies to be a mixture of *de jure* and *de facto* pegging -- thus providing these economies with some room for monetary policy independence -- by averaging the results reported in Tables 3.3 and 3.4 (see Table 3.5), the conclusion remains that the financial instability fall-out of the monetary policy cycle in the global core economy is much stronger in a world with emerging market economies than in a world without them, and that the scope for international coordination of monetary policies is less in a world with emerging market economies than in a world without them.

A final observation that should be made is that the scope for monetary policy coordination becomes even smaller if we introduce an asymmetry with regard to the sensitivity of financial instability in developed relative to emerging market economies. Following empirical evidence (Fouejieu Azange, 2013), it may be assumed that the key reserve-currency issuing economy (the United States) is endowed with a more resilient financial system and so attaching a lower weight to financial stability in its monetary policy objective function. As a result, financial assets that are denominated in that currency may serve as a safe haven in times of global financial stress. Although we do not model this explicitly, this would mean that the spillover of financial stability would be asymmetric. i.e. smaller in the direction from emerging market economies to developed economies and larger in the opposite direction. As a corollary, the welfare gains from

international coordination – in terms exposure to financial stress – would be biased towards the emerging market economy whereas the developed economy would still suffer the welfare loss from its monetary policy cycle being more out of whack with its business cycle. And hence the incentive for the developed economy to engage in international coordination of monetary policies would be even smaller.

Table 3.5: International spillover effects – a developed and an emerging market economy (mix of open and managed capital account and *de facto* and *de jure* fixed exchange rates)

	Nash/Stackleberg				Coordination			
Economy	Developed		Emerging		Developed		Emerging	
Period	0	1	0	1	0	1	0	1
Output	-1.0	1.2	1.9	-1.8	-1.5	2.1	1.7	-1.2
Interest rate	-4.0	3.8	-1.9	1.8	-3.5	2.9	-1.7	1.2
Exchange rate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Debt		8.0		3.7		7.0		3.3
Financial instability		30.7		13.1		20.9		7.8
Welfare loss	5.1		10.2		5.8		6.6	

Note: all variables in (%-point) deviations from baseline and computed as simple averages of the corresponding outcomes in Tables 3.3 and 3.4.

In sum, while there are many more interesting observations one can make, this analysis gives rise to the following overarching conclusions:

1. The entrance in the international monetary system of emerging market economies with still fragile financial systems, alongside the liberalisation of capital movements, has been one of the root causes of recurrent regional financial crises, regardless of whether these economies pursue a fixed exchange rate or a floating exchange rate regime against the dominant global reserve currency, though the channels are different.
2. In the case of *de jure* fixed exchange rates – such as Chinese case in which the exchange rate is managed by the monetary authorities as a means to preserve domestic financial stability – financial instability occurs because developed economies' monetary policies need to 'work harder' to achieve a desired level of macroeconomic stability in the absence of the support of exchange rate adjustment. This implies a tendency for debt in developing economies to drift up and an associated greater vulnerability to monetary policy tightening.
3. In the case of liberal capital flows, financial instability occurs because the emerging market economies' monetary policies are forced to align their monetary policies with that of the dominant global reserve currency issuer regardless of their own business cycle, thus fueling a domestic financial boom-bust cycle. In addition, they suffer from greater macroeconomic instability as their monetary policy is out of whack with their own business cycle.
4. Coordination of monetary policies across developing economies looks welfare enhancing, this is not the case for coordination between developed and emerging market economies. While the emerging market economies would gain from coordination, developed economies would lose. The reason is that – regardless of the exchange rate regime – the loss of monetary policy independence in the developed economies proves to be too costly.
5. However, a case could be made that this makes coordination of monetary policies among the developed economies even more rewarding. Not only would this have a beneficial welfare effect – via diminished financial instability – on them, but it would, by smoothing the time profile of the monetary policy cycle, also mitigate financial instability associated with the interaction with emerging market economies.

Finally, it could be argued that coordination of monetary policies is unnecessary insofar as countries coordinate other policies to address global financial instability risk. However, that approach would be confronted with the same type of externalities as monetary policy. In an integrated financial system, where instability spills over across borders, there is little incentive for any individual country to contain financial instability (Cecchetti and Schoenholtz 2017). So coordination of regulatory policies in the pursuit of financial stability is not necessarily easier to achieve than the coordination of monetary policies. Therefore, we think it would be better to hedge ones bets and pursue international coordination in both policy areas.

Conclusions

In this paper we have looked at the normalization of the US monetary policy against the international macro context where emerging markets economies depend on the dollar and on international capital markets for their liquidity and where the world's second largest economy, China, constraints the exchange rate and capital movements. Empirical evidence and the result of our stylized global model suggest that the US monetary policy needs to work harder to achieve the desired level of macro-economic stability as China constraints the adjustment of its exchange rate.

Countries that are at the receiving end of these spillovers have limited policy options and these are normally constrained by the amount of slack that exist in the economy. Currently the eurozone is gaining from the strong dollar in terms of exports, but that was not the case in 2011-2012 when an unusual strong euro exacerbated the already stagnant economy. But developing countries find it difficult to manage the impact of both an extremely accommodating US monetary policy and a normalization like the one that is currently under way.

There is a trade-off between short-term macroeconomic stabilization – i.e. output growth, job creation and price stability – and medium-term financial stability – i.e. the stability of the financial system and its capacity to fulfil its basic functions of financial intermediation and payments. The current international monetary system is structured in a way that complicate this trade-off, potentially leading to a too fast build-up of debt, when the US monetary policy is loose, and to greater vulnerability when the US monetary policy normalises. tightens.

For countries that can manage exogenous financial shocks – such as the developed economies – there are limited incentives to conduct their monetary policy to reduce financial instability in developing countries. The conclusion from our model is that having emerging markets economies in the monetary and financial system exacerbate the financial instability fall-out of the monetary policy cycle while it makes international monetary policy coordination more difficult. Coordination of monetary policies among developed countries would help emerging markets economies to mitigate financial instability.

There are two policy implications that we draw from our paper. The first is that on balance it is better to have coordination than not to have it. We suggest looking at coordination among developed countries not only in terms of reduced financial instability – i.e. their own welfare – but also as a way to smooth the monetary policy cycle and so mitigate financial instability associated with emerging markets economies.

The second policy implication is structural and deals with the entrance of emerging markets economies in the international monetary system and the liberalization of capital movements. These are financially fragile countries and over the last 30 years have been at the core of financial instability. They are often unable to manage the trade-off between short-run macroeconomic stabilization and median-run financial stability. Private-sector flows, which have increased massively between 2008 and 2017, complicate this trade-off, potentially leading to a too fast build-up of debt and large vulnerabilities. All this tends to unfold in the face of events like monetary policy normalization.

Global and regional safety nets are deployed when a country – or countries – faces a financial crisis, but they are ex-post, crisis-crisis-resolution measures. We need a robust system for crisis prevention where the build-up of vulnerabilities and related risks are monitored and dealt with before they become unmanageable. Therefore, international policy action should focus on addressing the fault lines of the current international monetary and financial system with the aim not only to move forward the reform that was mentioned in the aftermath of the global financial crisis. International policy action should also monitor and prevent the build-up of the next crisis and focus on creating a robust system of crisis prevention - and not just on ensuring that the appropriate financial safety nets are in place for when a crisis occurs.

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Annex A Econometrics

Most symbols are defined in the main text unless otherwise mentioned.

In the long run financial instability (gauged by the VIX) is a function of debt and the interaction between debt and the federal funds rate, as follows:

(A.1) $$V_t = a\left(D_{t-j} - D^*\right) + b\left(D_{t-j} - D^*\right)r_{t-j} + c, j = 0,1,2, \ldots$$

Volatility is a function of the 'debt gap' which is the difference between the actual debt ratio and a fixed threshold debt ratio D^*.

We embed this in the following error correction framework:

(A.2) $$\Delta V_t = -h\left[V_{t-1} - a\left(D_{t-j-1} - D^*\right) - b\left(D_{t-j-1} - D^*\right)r_{t-j-1} - c\right]$$

This can be rearranged as:

(A.3) $$\Delta V_t = -hV_{-1} + ha\left(D_{-j-1} - D^*\right) + hb\left(D_{-j-1} - D^*\right)r_{-j-1} + hc$$

We estimate:

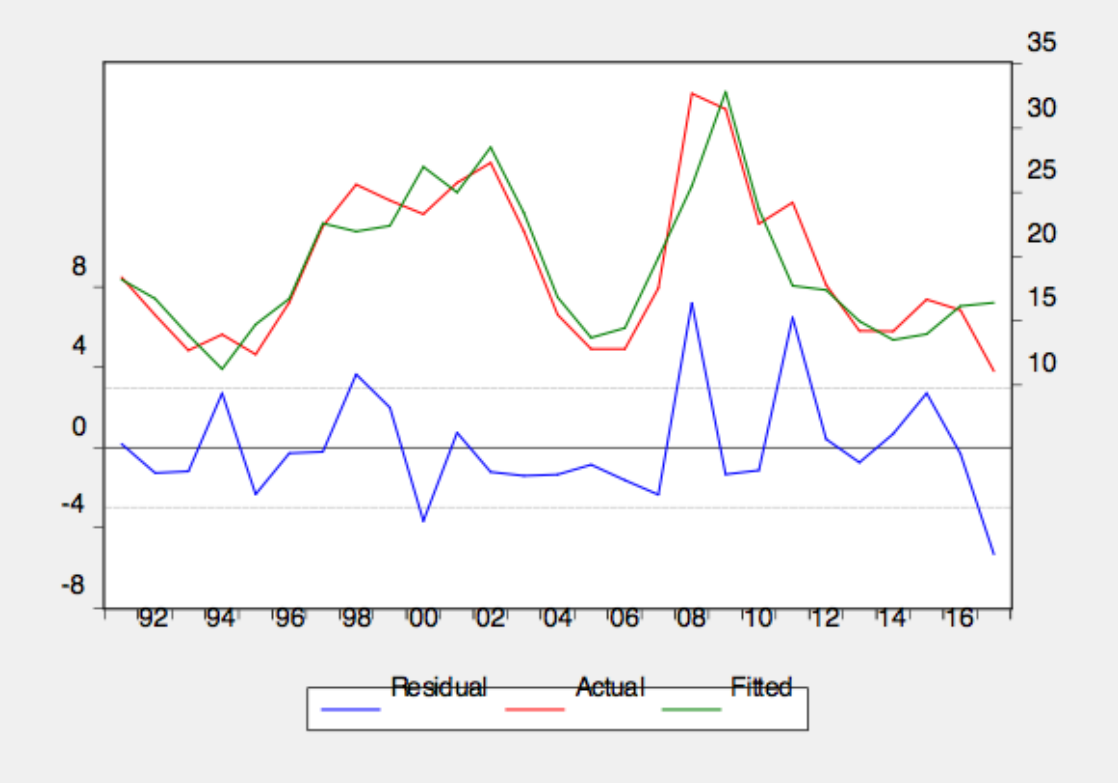
(A.4) $$\Delta V_t = b_0 + b_1 V_{t-1} + b_2 D_{t-j-1} + b_3 r_{t-j-1} + b_4\left(D_{t-j-1}.r_{t-j-1}\right)$$

Where:

$$b_0 = -h(aD^* - c),\ b_1 = -h,\ b_2 = ha,\ b_3 = -hbD^*,\ b_4 = hb$$

The regression result reads (t-statistics in brackets):

$$\Delta V = -33.1 - 0.60V_{-1} + 0.20D_{-2} - 10.6r_{-2} + 0.07(D_{-2}.r_{-2}),\ R^2 = 0.62,\ DW = 2.2$$
$$(-1.9)(-5.4)(2.3)(-3.6)(4.4) \quad Sample: 1991 - 2017$$



We identify the structural parameters of the model as follows:

$$h = -b_1 = 0.6$$

$$a = b_2/h = \frac{0.2}{0.6} = 0.33$$

$$b = b_4/h = \frac{0.07}{0.6} = 0.12$$

$$D^* = -\frac{b_3}{hb} = \frac{10.6}{0.6 \times 0.12} = 147$$

$$c = \frac{b_0 + haD^*}{h} = \frac{-33.1 + 0.6 \times 0.33 \times 147}{0.6} = -6.7$$

We assume global debt in the long run to be a negative function of the federal funds rate. However, because there are trends in both variables it is more efficient to estimate in first differences, which yields:

(A.5) $\Delta D_t = e\Delta r_t + fV_{t-j} + g$

Here is g the autonomous time trend in the debt ratio. In preparatory regressions we also found evidence of the VIX entering the equation with a time lag, which can be interpreted as volatility having a negative impact on debt formation via risk aversion. We expect $e < 0$ and $f < 0$.

Embedding this in an error correction framework yields:

(A.6) $\Delta^2 D_t = -k\left(\Delta D_{t-1} - e\Delta r_{t-1} - fV_{t-1-j} - g\right)$

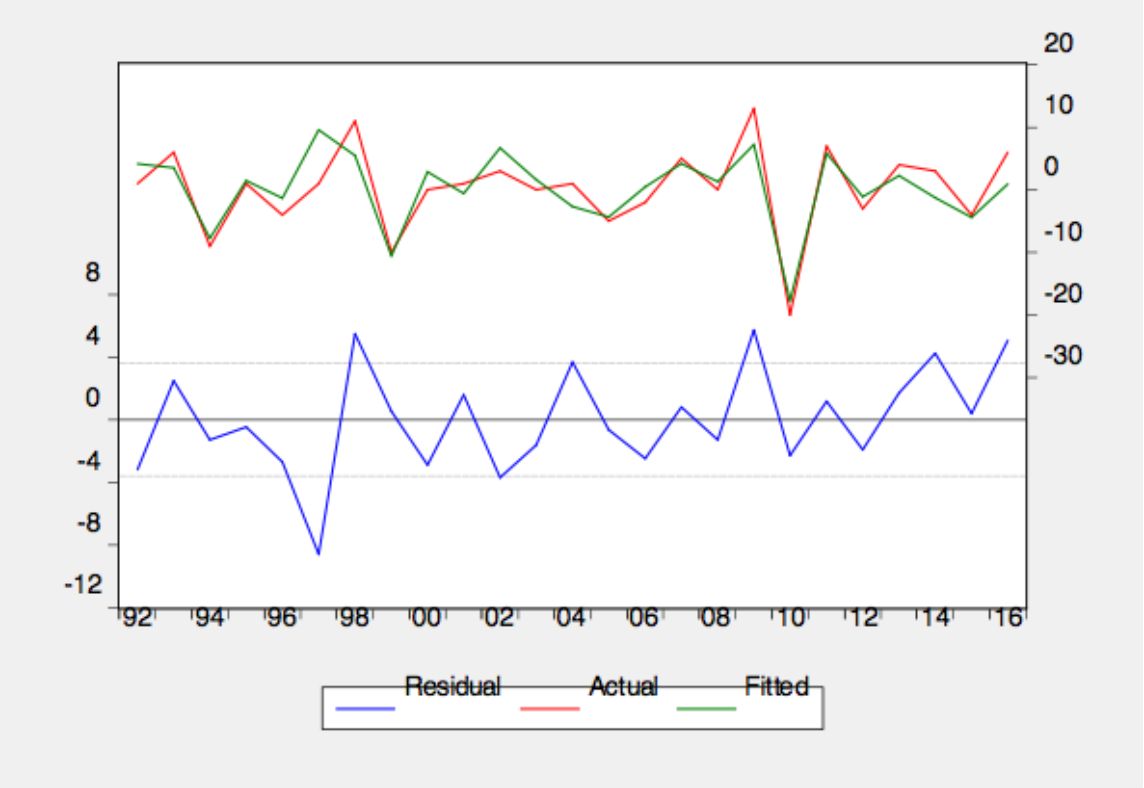
The regression equation then reads:

(A.7) $\Delta^2 D_t = c_0 + c_1\Delta D_{t-1} + c_2\Delta r_{t-1} + c_3 V_{t-1-j}$

where $c_0 = kg, c_1 = -k, c_2 = ke, c_3 = kf$

The regression result reads (t-statistics in brackets):

$$\Delta^2 D = 7.7 - 1.37\Delta D_{-1} - 2.3\Delta r_{-1} - 0.27V_{-2}, R^2 = 0.73, DW = 2.3$$
$$(2.9)(-7.6)(-3.8)(-2.1) Sample: 1992 - 2016$$



We identify the structural parameters as follows:

$$k = -c_1 = 1.37$$

$$g = \frac{c_0}{k} = \frac{7.7}{1.37} = 5.5$$

$$e = \frac{c_2}{k} = \frac{-2.3}{1.37} = -1.7$$

$$f = \frac{c_3}{k} = \frac{-0.27}{1.37} = -0.2$$

Annex B Derivation of monetary policy reaction functions

Minimizing the welfare loss functions (3.10) subject to equations (3.6) to (3.9) yields the following Nash solution for the policy reaction functions:

$$\text{(B1)} \quad \begin{cases} r_0 = \frac{1}{\varphi'\Delta'}\left[\omega\chi r_0^* + u_0 + \beta\frac{\alpha_1\gamma\delta}{\varphi'^2}(\omega\chi r_1^* + u_1)\right] \\ r_1 = \frac{\omega}{\varphi'\Delta'}\left[\omega\chi r_1^* + u_1 + \frac{\alpha_1\gamma\delta}{\varphi'^2}(\omega\chi r_0^* + u_0)\right] \end{cases}$$

$$\text{(B2)} \quad \begin{cases} r_0^* = \frac{\omega}{\varphi'\Delta'}\left[\omega\chi r_0 + u_0^* + \beta\frac{\alpha_1\gamma\delta}{\varphi'^2}(\omega\chi r_1 + u_1^*)\right] \\ r_1^* = \frac{\omega}{\varphi'\Delta'}\left[\omega\chi r_1 + u_1^* + \frac{\alpha_1\gamma\delta}{\varphi'^2}(\omega\chi r_0 + u_0^*)\right] \end{cases}$$

where $\Delta' = 1 - \beta\left(\frac{\alpha_1\gamma\delta}{\varphi'^2}\right)^2$, $\varphi' = \varphi + \omega\chi$.

Minimizing the welfare loss functions (3.15) subject to equations (3.6) to (3.9) yields the following cooperative solution for the policy reaction functions:

$$\text{(B5)} \quad \begin{cases} r_0 = \frac{1}{\varphi'\Delta''}\left[\omega\chi r_0^* + u_0 + \beta\frac{(\alpha_1+\alpha_2)\gamma\delta}{\varphi'^2}(\omega\chi r_1^* + u_1)\right] \\ r_1 = \frac{1}{\varphi'\Delta''}\left[\omega\chi r_1^* + u_1 + \frac{(\alpha_1+\alpha_2)\gamma\delta}{\varphi'^2}(\omega\chi r_0^* + u_0)\right] \end{cases}$$

$$\text{(B6)} \quad \begin{cases} r_0^* = \frac{1}{\varphi'\Delta''}\left[\omega\chi r_0 + u_0^* + \beta\frac{(\alpha_1+\alpha_2)\gamma\delta}{\varphi'^2}(\omega\chi r_1 + u_1^*)\right] \\ r_1^* = \frac{1}{\varphi'\Delta''}\left[\omega\chi r_1 + u_1^* + \frac{(\alpha_1+\alpha_2)\gamma\delta}{\varphi'^2}(\omega\chi r_0 + u_0^*)\right] \end{cases}$$

where $\Delta'' = 1 - \beta\left[\frac{(\alpha_1+\alpha_2)\gamma\delta}{\varphi'^2}\right]^2$, $\varphi' = \varphi + \omega\chi$.

Minimizing the welfare loss functions (3.10) subject to equations (3.6) to (3.9) and $\chi = 0$ yields the following Nash solution for the policy reaction functions under a fixed exchange rate regime:

$$\text{(B7)} \quad \begin{cases} r_0 = \frac{1}{\varphi\Delta}\left[u_0 + \frac{\beta\alpha_1\gamma\delta u_1}{\varphi^2}\right] \\ r_1 = \frac{1}{\varphi\Delta}\left[\frac{\alpha_1\gamma\delta u_0}{\varphi^2} + u_1\right] \end{cases}$$

$$\text{(B8)} \quad \begin{cases} r_0^* = \frac{1}{\varphi\Delta}\left[u_0^* + \frac{\beta\alpha_1\gamma\delta u_1^*}{\varphi^2}\right] \\ r_1^* = \frac{1}{\varphi\Delta}\left[\frac{\alpha_1\gamma\delta u_0^*}{\varphi^2} + u_1^*\right] \end{cases}$$

where $\Delta = 1 - \beta\left(\frac{\alpha\gamma\delta}{\varphi^2}\right)^2$.

This solution can simply be derived by assuming $\chi = 0$ in the policy reaction functions (B1) and (B2).

Minimizing the welfare loss functions (3.15) subject to equations (3.6) to (3.9) and $\chi = 0$ yields the following cooperative solution for the policy reaction functions under a fixed exchange rate regime:

$$\text{(B9)} \quad \begin{cases} r_0 = \frac{1}{\omega\Delta'''}\left[u_0 + \frac{+\beta(\alpha_1+\alpha_2)\gamma\delta u_1}{\varphi^2}\right] \\ r_1 = \frac{1}{\omega\Delta'''}\left[\frac{(\alpha_1+\alpha_2)\gamma\delta u_0}{\varphi^2} + u_1\right] \end{cases}$$

$$\text{(B10)} \quad \begin{cases} r_0^* = \frac{1}{\omega\Delta'''}\left[u_0^* + \frac{\beta(\alpha_1+\alpha_2)\gamma\delta u_1^*}{\varphi^2}\right] \\ r_1^* = \frac{1}{\omega\Delta'''}\left[\frac{(\alpha_1+\alpha_2)\gamma\delta u_0^*}{\varphi^2} + u_1^*\right] \end{cases}$$

where $\Delta''' = 1 - \beta\left[\frac{(\alpha_1+\alpha_2)\gamma\delta}{\varphi^2}\right]^2$.

This solution can simply be derived by assuming $\chi = 0$ in the policy reaction functions (B5) and (B6).

Assuming that $\chi \longrightarrow \infty$ in the policy reaction function (B2) yields the following policy reaction function for the Stackleberg follower:

$$\text{(B11)} \quad \begin{cases} r_0^* = \lim\limits_{\chi\to\infty} \frac{1}{\varphi'\Delta''}\left[\omega\chi r_0 + u_0^* + \beta\frac{(\alpha_1+\alpha_2)\gamma\delta}{\varphi'^2}(\omega\chi r_1 + u_1^*)\right] = r_0 \\ r_1^* = \lim\limits_{\chi\to\infty} \frac{1}{\varphi'\Delta''}\left[\omega\chi r_1 + u_1^* + \frac{(\alpha_1+\alpha_2)\gamma\delta}{\varphi'^2}(\omega\chi r_0 + u_0^*)\right] = r_1 \end{cases}$$

where $\Delta'' = 1 - \beta\left[\frac{(\alpha_1+\alpha_2)\gamma\delta}{\varphi'^2}\right]^2$, $\varphi' = \varphi + \omega\chi$.

From (B11) and equation (3.7) follows that $r_t - r_t^* = e_t = 0$ (*de facto* fixed exchange rate). Inserting this equality in the policy reaction function (B1) yields the following policy reaction function for the Stackleberg leader:

$$\text{(B12)} \quad \begin{cases} r_0 = \frac{1}{\varphi\Delta'''}\left[u_0 + \beta\frac{(\alpha_1+\alpha_2)\gamma\delta}{\varphi^2}u_1\right] \\ r_1 = \frac{1}{\varphi\Delta'''}\left[u_1 + \frac{(\alpha_1+\alpha_2)\gamma\delta}{\varphi^2}u_0\right] \end{cases}$$

where $\Delta''' = 1 - \beta\left[\frac{(\alpha_1+\alpha_2)\gamma\delta}{\varphi^2}\right]^2$.

Similarly, taking policy reaction functions (B5) and (B6) as a starting point and assuming that $\chi \longrightarrow \infty$ yields the following policy reaction functions under coordination:

$$\text{(B13)} \quad \begin{cases} r_0 = \frac{1}{\varphi\Delta''''}\left[u_0 + \beta\frac{2(\alpha_1+\alpha_2)\gamma\delta}{\varphi^2}u_1\right] \\ r_1 = \frac{1}{\varphi\Delta''''}\left[u_1 + \frac{2(\alpha_1+\alpha_2)\gamma\delta}{\varphi^2}u_0\right] \end{cases}$$

$$\text{(B14)} \quad \begin{cases} r_0^* = r_0 \\ r_1^* = r_1 \end{cases}$$

where $\Delta'''' = 1 - \beta\left[\frac{2(\alpha_1+\alpha_2)\gamma\delta}{\varphi^2}\right]^2$.