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Central Bank Balance Sheet Policies and Spillovers to Emerging Markets

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Abstract

We develop a theoretical model that shows that in the near future, the monetary policies of some key central banks in advanced economies (AEs) will have two dimensions—changes in short-term policy rates and balance sheet adjustments. This will affect emerging market economies (EMs), especially those with a pegged exchange rate, as these EMs primarily use a single monetary policy tool, i.e., the short-term policy rate. We show that changes in policy rates and balance sheet adjustments in AEs may differ in their respective financial spillovers to pegged EMs. Thus, it will be difficult for EMs to mitigate different types of spillovers with a single monetary policy tool. In that context, we use the model to show how EMs might use additional tools—capital controls and/or macro-prudential policy—to complement their monetary policy and financial stability toolkit. We also discuss how balance sheet adjustments that affect long-term interest rates may percolate to influence short-term interest rates via financial plumbing.

JEL Classification Numbers: G21; G28; F33; K22

Keywords: financial spillovers; collateral; RRP (reverse repo program); fed funds rate; General Collateral Finance (GCF rate); macro-prudential; capital control; quantitative easing

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GLOSSARY

AE:	Advanced Economies
ASW:	Araujo, Schommer, and Woodford (2015)
CFM:	Capital Flow Measures
DTCC:	Depository Trust and Clearing Corporation
EM:	Emerging Markets
EMB:	Emerging Market Bonds
FF:	Federal Funds
FFR:	Federal Funds Rate
FGP:	Fostel, Geanakoplos, and Phelan (2017)
GFC:	General Collateral Finance
GSD:	Government Securities Division
HK:	Hong Kong
IOER:	Interest on excess reserves
OTC:	Over-the-Counter
QE:	Quantitative Easing
RRP:	Reverse repo purchase
SOMA:	System Open Market Account
U.S.:	United States
UST:	United States Treasuries

I. INTRODUCTION

Short-term policy rates in many advanced economies (AEs) have remained persistently low since the aftermath of the recent financial crisis. In an effort to manage sluggish economic recoveries and reinvigorate growth, several leading central banks (e.g., the Federal Reserve in the U.S., the Bank of England, the European Central Bank, and the Bank of Japan) have carried out several rounds of quantitative easing (QE) to provide further monetary stimulus. A lively empirical literature suggests that QE policies in AEs have generated spillovers to emerging market economies (EMs), in particular. This has raised concerns about the sharp increase in cross-border financial volatility. While the empirical evidence for QE's financial spillovers is well documented, the economic explanation of its international transmission remains relatively obscure. This paper provides a theoretical framework to study the financial spillovers of QE, and QE unwind by the Fed (FOMC, 2017).[2] Brainard (2017) suggests that cross-border spillovers will have important implications if policy rate hikes and balance sheet reductions are not equivalent.

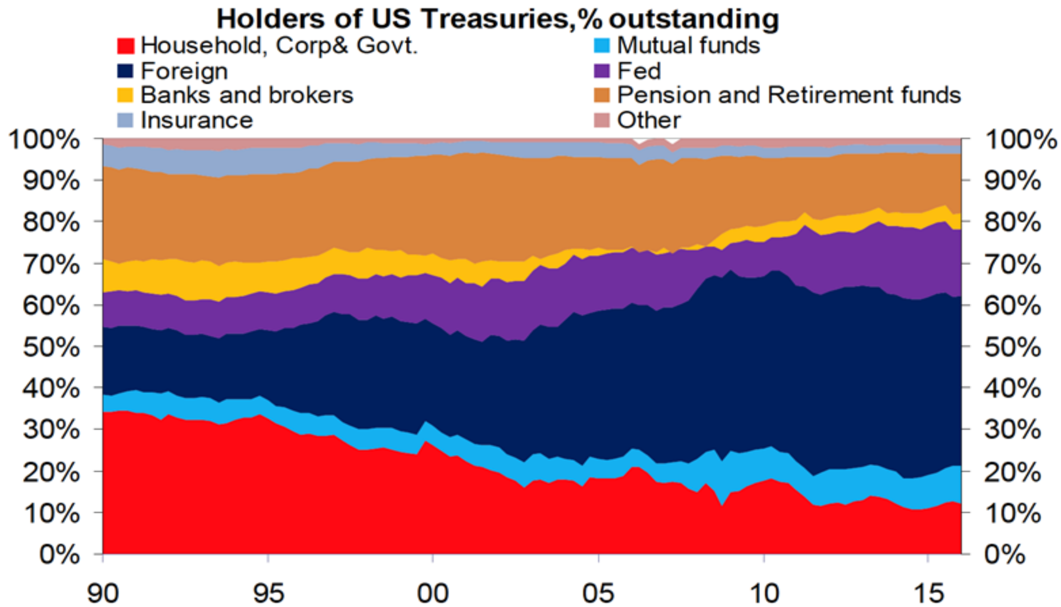
We show that conventional interest-rate policy and balance sheet adjustments consist of two independent dimensions of monetary policy in some AEs; furthermore, these two independent policy tools differ in their respective financial spillovers to EMs. We analyze the policy limitations EMs face in response to potential balance sheet adjustments in AEs, and discuss possible policy options for EMs to complement such incomplete arrangements.

While QE's international spillovers can operate via many channels, this paper focuses on a collateral channel of transmission, different from the traditional financial accelerator model. In this context, the collateral channel is essential for two reasons. First, since the onset of QE, a large fraction of the assets acquired by AE central banks (e.g., U.S. Treasuries (UST)) has traditionally consisted of bonds often used as collateral, including to facilitate collateralized cross-border funding. For example, international investors in AE government bonds obtain easy access to cross-border funding by pledging the underlying securities as collateral in the repo, securities lending, prime brokerage, and derivatives markets. The collateral properties of AE government bonds were further reinforced by the increased risk aversion and changing regulatory landscape that led to a growing demand for high-quality liquid assets (i.e., good collateral) after the financial crisis. Second, as QE has involved massive purchases of this important collateral, AE central banks' absorption of high-quality collateral from the private market has raised concerns about QE's potential disruption of the collateral market's proper functioning.

As an example of AE government bonds, consider US Treasury bills, or notes, or bonds. (UST). Although estimates vary, it is well-known that a large share of UST has always been held outside the U.S. by foreign investors and central banks (see Figure 1). Furthermore, UST have traditionally been among the most widely accepted collateral in the cross-border funding market. Therefore, it is important to study how the Federal Reserve's balance sheet adjustments might interact with collateralized cross-border funding via the collateral channel.

[2] Federal Open Market Committee, February meeting minutes (released, March 2017): "*that a change to the Committee's reinvestment policy would likely be appropriate later this year*."

Figure 1. Ownership of U.S. Treasuries



Source: Deutsche Bank

This paper develops a framework that features two stylized countries—which we call the U.S. and the EM—that differ in the collateral values of their assets.[3] Each country consists of private-sector agents and a central bank. Each country issues long-term government bonds denoted by UST and EMB (Emerging Market Bonds). All private borrowing must be secured by collateral and internationally, only UST can serve as collateral in the cross-border funding market.[4] The Federal Reserve not only has effective control over the short-term policy rate (consistent with conventional monetary policy), but can also engage in QE in the form of direct purchases of UST (financed by issuing riskless central bank reserves) to affect the long-term interest rate.

In our model, agents that face collateral constraints prefer UST over EMB, because UST can serve as collateral to obtain funding. Global demand for collateral and collateral-backed financial claims supports the collateral value of UST and results in its higher price relative to EMB, ceteris paribus. In equilibrium, UST enjoys a collateral premium over EMB. In our model the collateral premium may come from two sources: (a) capital controls on EM agents that limits their purchase of UST, and (b) increased demand for high quality liquid assets such as UST due to QE by central banks and new regulations.[5]

[3] We take the U.S. as an example of AEs for illustrative purposes. Our model is general and should apply to the situation between other AEs (e.g., the Eurozone) and EMs.

[4] Our assumption that all borrowing must be collateralized is for simplicity; it can be relaxed without affecting key results. For example, it could equally be assumed that only part of the private borrowing must be collateralized. Similarly, the assumption that only UST can serve as collateral can also be relaxed, so long as UST are assumed to have higher collateral value than EMB.

[5] An extension of the model suggests that removing capital control in EMs would further increase the collateral premium of UST.

Unlike private agents, the Federal Reserve can finance its asset purchases by issuing central bank reserves elastically without any collateral constraints.[6] This allows the Fed to raise the price of UST under binding collateral constraints. While global demand for collateral and collateral-backed finanical promises support the collateral value of UST, sufficiently large QE results in (i) a widening of international spreads and (ii) a subsequent portfolio shift by AE agents toward higher-return EMB. This type of international portfolio shift may weaken or even reverse the marginal effect of ever-larger QE interventions on the price of UST. In our model, while QE increases U.S. agents' relative holdings of EMB, EM demand for UST remains relatively stable (in response to QE) due to persistent EM demand for collateral.

An integral part of the paper is to examine the unwind of QE and its implications for EM. Two scenarios are considered: (i) the AE central bank only adjusts the short-term policy rate (while maintaining its balance sheet) and (ii) the AE central bank unwinds its balance sheet by selling its UST holdings. Our analysis suggests that these two policies have different implications for EMs. In the former scenario, the EM central bank can mitigate financial spillovers by simply aligning its short-term policy rate with the AE central bank. In the latter case, however, there is no simple policy alignment with which EMs can offset cross-border financial spillovers and risks to financial stability. We use the model to illustrate how capital controls and macro-prudential policy might be viable complements in the latter scenario.[7]

Overall, our analysis suggests that many EMs, especially those that are pegged (e.g., Hong Kong and Gulf countries) or quasi-pegged as in several countries in the Asian-dollar block (i.e., exchange rate is anchored against an AE such as the U.S.), may need to assess their policy tools in response to cross-border financial spillovers. (Our paper does not analyze EMs with flexible exchange rates). Our analysis also suggests that EM central banks have little control over their domestic yield curve (Naudon and Yany, 2016).

Going forward monetary policy in some AEs may act along two dimensions— a conventional policy rate as well as balance sheet adjustments. On the other hand, many EMs with pegged exchange rates may continue to rely on a single monetary tool that mimics moves in AEs' short-term policy rates. The "Trilemma" postulation suggests that by giving up monetary independence and keeping short-term interest rates aligned with the anchor country, EMs can maintain a fixed nominal exchange rate even under free capital flows. Our analysis suggests that with the use of balance sheet adjustments in AEs, simply aligning the short-term policy rate will no longer be sufficient in shielding EMs from external monetary spillovers. Balance sheet adjustment in AEs can create additional gaps in long-term interest rates, and trigger additional monetary and financial stability spillovers even when the short-term interest rates are well aligned.

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[6] Here the Federal Reserve, a financial intermediary, is capable of affecting asset prices because it is not subject to any collateral requirement, which represents a significant advantage over private financial intermediaries. Collateral requirements are a form of financial friction in the model, and, therefore, "Wallace Neutrality" does not hold.

[7] Although we use capital controls interchangeably with CFM (capital flow management), the IMF's institutional view considers CFM as a broader concept and comprises residency based measures including taxes and regulations that impact cross-border financial activity. CFM also includes non-residency based measures that limit capital flows. Macroprudential measures are designed to limit financial stability risks that are associated with capital flows.

The rest of the paper is organized as follows: Section II provides a brief literature review of previous work on the spillover effects of QE. Section III presents a two-country general equilibrium model with both conventional and unconventional monetary policies. Section IV presents major quantitative results from our model. We analyze different scenarios for the unwind of QE and discuss possible policy options for EMs seeking to counteract the associated financial spillover. In Section V we discuss the policy implications of our results and conclude.

II. Literature Review

Our paper is related to several strands of literature. The policy question we seek to explore relates to the vast empirical literature on QE's financial spillovers. Among many others, Fratzscher et al. (2011) analyze the spillover effects of QE in the U.S., and find that earlier phases of QE tend to have stronger effects on cross-border asset prices. They also find that capital flowed out of EMs to the U.S. under QE 1, and went in the opposite direction under QE 2. Chen et al. (2015) systematically estimate both the financial and macroeconomic impacts of QE using a global vector error-correction model, and find that QE in the U.S. has had more pronounced impacts on EMs than on other AEs; however, there is considerable heterogeneity across countries. Cho and Rhee (2013) conduct a panel analysis of QE's impacts on Asian economies and find that countries with more open and developed capital markets have experienced greater swings in cross-border inflows during QE episodes, while countries with more stable exchange rates tend to experience greater asset price inflation. Identification of QE's financial spillovers is generally challenging, due to many other factors that can affect cross-border asset prices and capital flows, such as relative growth prospects, global risk aversion, etc., not to mention the associated endogeneity issue. (See, for instance, IMF WEO (2016 April) and Clark et al. (2016)). Nevertheless, empirical studies in general suggest sizeable cross-border spillover effects from AEs' QE.

Despite this abundance of empirical studies, only limited theoretical work has been conducted to examine QE's international transmission. Our two-country model builds on studies conducted by Araujo, Schommer, and Woodford (2015); Fostel, Geanakoplos, and Phelan (2017); and Geanakoplos and Wang (2017). In a single-economy context, Araujo, et al. (ASW henceforth) develop a framework to study how the central bank's purchases of collateral-like assets might interfere with private agents' collateral constraints and impact asset prices. Fostel, et al. (2017) (FGP henceforth) develop a model that shows that financial integration can arise as a result of international sharing of scarce collateral. Geanakoplos and Wang builds on ASW and FGP to determine how the central bank's purchases of collateral-like assets might interfere with collateralized cross-border funding and, subsequently, generate financial spillovers. We extend Geanakoplos and Wang's model with a particular focus on QE's unwind and its implications for EMs. This strand of work follows the collateral equilibrium models developed by Geanakoplos (1997) and Geanakoplos and Zame (2013), who focus on the effects of collateral on asset prices and real investment. As both studies demonstrate, much of the lending in modern economies is secured by some form of collateral, a feature that is often overlooked in conventional economic models.

We believe that collateral also plays an important role in QE's international transmission for two important reasons. First, much of the cross-border flows are secured via standard documentations such as global repo, derivatives, and securities lending agreements. Second, the bulk of assets involved in QE, such as UST, are traditionally important collateral that

facilitate collateralized cross-border flows; how QE's absorption of high-quality collateral affects collateralized cross-border funding, therefore, is particularly relevant.
A recent report by the Bank of International Settlement reinforces the need to closely monitor monetary policy's impact on the collateral market.[8]

Our paper is also related to the growing literature that studies policy tools for EMs seeking to mitigate external financial spillovers and improve financial stability. Forbes et al. (2015) use a propensity score matching methodology to study the effectiveness of capital flow management measures (CFMs) in achieving various policy targets. They find that certain macroprudential policies are effective in improving measures related to financial fragility (e.g., bank leverage, bank credit growth, and exposure to foreign liabilities). Capital controls are similarly found to be helpful in reducing private credit growth. Blanchard (2016) develops a two-country Mundell–Fleming model to study the impacts of AEs' macroeconomic policies on EMs' goods, foreign exchange, and financial markets. He concludes that capital control is more effective than foreign exchange intervention in achieving desired macroeconomic outcomes. IMF (2014) discusses spillovers to EMs in the aftermath of the so-called Taper Tantrum (i.e., the period of turbulence triggered by the Fed's announcement of a gradual unwinding of its QE program), in the summer of 2013. In particular, the paper highlights the high correlation between capital inflows to EMs and the Fed's QE program post the 2008 crisis. IMF (2015) highlights the IMF's institutional view on the management of capital flows and takes stock of both macroprudential and capital flow management measures, including definitional aspects that may differ from the market's vocabulary.

This paper looks at the potential need for some EMs to use capital controls and macroeconomic tools to mitigate against balance sheet unwind of AEs central banks. However, there will be costs to EMs using such tools. Since the costs/benefits will be specific (and time-varying) to each EM, associated welfare analysis will be required to gauge the extent to which such tools should be implemented.

III. A Two-Country General Equilibrium Model with Collateral Constraints and Monetary Policy

We present a simple extension of the model in Geanakoplos and Wang (2017).[9] Consider a simple endowment economy with two countries: an AE and an EM. Time is discrete, and there are two periods: t=0,1. There are two possible states in period 1: (U, D) where U stands for the "Up" state and D for the "Down" state. Agents in both economies consume a single consumption good C. Each economy has two kinds of government bonds. The first is a riskless bond that is analogous to short-term government bonds, such as Treasury bills. The riskless bond pays one unit of money in both U and D, and their payoffs (promises) will be paid by the issuing government from tax revenues. For simplicity, we assume that there is a fixed exchange rate (equal to one) between the AE and the EM. Denote the riskless bond as B.

[8] Central Bank Operating Frameworks and Collateral Market, CGFS Publications No. 53.

[9] Readers can refer to Geanakoplos and Wang (2017) for more details about the model setup. The model is abstract and may not be applicable to all practical policy choices.

The second type of government bond is a risky real bond and is analogous to long-term government bonds, whose payoff (e.g., par value) can vary across different states in the second period.[10] Denote the long-term government bonds in each country by (Y_{AE}, Y_{EM}). The payoff vectors of Y_{AE} and Y_{EM} are given exogenously by (d_U^{AE}, d_D^{AE}) and (d_U^{EM}, d_D^{EM}). Here Y_{AE} is analogous to UST, while Y_{EM} is analogous to EMB. A key distinction between Y_{AE} and Y_{EM} is that only Y_{AE} can serve as collateral to obtain collateralized funding in the cross-border market. [11]

A. Initial Endowment

There is a finite set of agents in both the AE and the EM, denoted by $\mathcal{H}$ and $\mathcal{H}^*$ respectively. Agents in each country are endowed (e) with period-0 consumption good for AE ($e_{C_0}^h$) and EM ($e_{C_0}^{h^*}$) respectively; their respective risky bonds Y_{AE} for the AE agent (or, $e_{Y_{AE}}^h$), and Y_{EM} ,for the EM agent ($e_{Y_{EM}}^{h^*}$); a riskless government bond B; and period-1 consumption good C, written as follows:

$$(e_{C_0}^h, e_{Y_{AE}}^h, e_B^h, \{e_{C_s}^h\}_{s\in\{U,D\}}) \text{ for } h \in \mathcal{H}.$$

$$(e_{C_0}^{h^*}, e_{Y_{EM}}^{h^*}, e_B^{h^*}, \{e_{C_s}^{h^*}\}_{s\in\{U,D\}}) \text{ for } h^* \in \mathcal{H}^*.$$

All notations with asterisk * denote variables for the EM.

B. Privately-Traded Financial Contracts

Agents can borrow from one another in the form of issuing financial claims. Denote the set of feasible financial claims by J. A financial claim $j \in J$ specifies the nominal repayment (j_U, j_D) in both states (U, D), and the amount of collateral Y_{AE} required to secure the contract. For simplicity assume that all financial claims are non-contingent, so that $j_U = j_D = j$. Further assume that each unit of financial claim must be secured by one unit of Y_{AE}. A unit of financial claim j can therefore be written as $\big((j, j); one\ unit\ of\ Y_{AE}\big)$. Denote the price of one unit of financial claim j by q_j.

Therefore, an agent can borrow q_j units of money in period 0 by issuing/selling a unit of financial contract j. The agent effectively promises nominal repayment (j, j) in period 1 and needs to own one unit of Y_{AE} as collateral to back his financial promises. Agents can buy or sell arbitrary quantities of a given financial claim at its competitive per unit price.

As in Geanakoplos and Zame (2014), agents cannot be coerced into honoring their promised repayment except by seizing the collateral used to back the financial contract. Therefore, the actual delivery of one unit of financial claim j in period-1 would be: $\min\{j, p_s d_s^{AE}\}$, where

[10] We do not seek to model the maturity structure of long-term government bonds. Instead we focus on its riskiness (risk premium) relative to short-term government bonds.

[11] As mentioned in footnote 3, the assumptions here are for simplicity and can be relaxed without changing our key results.

$p_s d_s^{AE}$ [12] represents the value of the collateral. Denote the amount of financial claim $j \in J$ *purchased* by agent h by ψ_j^h and the amount of financial claim $j \in J$ *issued* by agent h by φ_j^h.

C. **Monetary Policy Specification**

We assume the existence of a central bank in AE that can implement QE in the form of purchasing risky Y_{AE} by issuing riskless and interest-bearing central bank reserves. Interest on central bank reserves determines the riskless rate of return in the economy and represents conventional interest rate policy in our model. The amount of Y_{AE} acquired by the AE central bank is denoted by y_{AE}^{CB}. As in ASW (2015), we assume that the AE central bank here is a monetary-fiscal authority and is obligated to collect taxes in period 1 (i.e., the terminal period) to retire all public debt and reimburse/make up for any earnings/losses from its asset purchases.

Since this is a finite-horizon model, the AE central bank must specify the value of money (in terms of the consumption good) in the terminal period. This is necessary to pin down expectations about the real value of the interest rate i the AE central bank promises to pay in period 1. We assume that the AE central bank is able to fix the price of the consumption good in period 1 at $\{p_s\}_{s\in\{U,D\}}$.

Lastly, as mentioned earlier, we assume that there is a fixed exchange rate equal to one between the AE and the EM, and by default this implies that $i = i^*$. We do not consider the EM central bank's asset purchases in this paper.

Therefore, the complete monetary specification in the economy can be written as follows:

$$(i, b^{CB}, y_{AE}^{CB}, \{p_s\}_{s\in\{U,D\}})$$

A more detailed explanation of the general model setup can be found in ASW (2015) and Geanakoplos and Wang (2017).

D. **Agent Maximization for the Advanced Economy (AE)**

$$\max_{c^h\geq 0,\psi^h\geq 0,\varphi^h\geq 0,\mu^h\geq 0,y_{AE}^h\geq 0,y_{EM}^h\geq 0} u^h(c^h) \quad s.t.$$

$$p_0 c_0^h + \sum_{j=1}^J q_j(\psi_j^h - \varphi_j^h) + \pi_{AE} y_{AE}^h + \pi_{EM} y_{EM}^h + (1+i)^{-1}\mu^h \leq p_0 e_{C_0}^h + \pi_{AE} e_{Y_{AE}}^h + (1+i)^{-1} e_B^h, \tag{1}$$

$$p_s c_s^h \leq p_s\left(e_{C_s}^h + y_{AE}^h d_s^{AE} + y_{EM}^h d_s^{EM}\right) + \sum_{j=1}^J (\psi_j^h - \varphi_j^h)\min\{j, p_s d_s^{AE}\} + \mu^h - \theta^h(\mu - p_s y_{AE}^{CB} d_s^{AE}),\ \forall s \in \{U, D\} \tag{2}$$

$$y_{AE}^h \geq \sum_{j=1}^J \varphi_j^h, \tag{3}$$

[12] We assume that one unit of Y_{AE} delivers d_s^{AE} units of consumption good in state s of period 1. p_s is the price of the consumption good in state s.

where $p = (p_0, \{p_s\}_{s \in \{U,D\}})$ are the prices of consumption goods in each state of the world; $q = \{q_j\}_{j \in J}$ are the prices of financial contracts in J; $\pi = (\pi_{AE}, \pi_{EM})$ are the prices of (Y_{AE}, Y_{EM}); μ^h denotes household h's total holding of riskless assets, including both riskless government bond and riskless central bank reserves; $\mu = \sum_{h=1}^{\mathcal{H}} \mu^h$ is the total outstanding public debt (riskless government bonds and central bank reserves); and θ^h is the tax share of agent h.

Equation (1) represents agent h's period-0 budget constraint, which says that the expenditure on consumption + expenditure on asset portfolio $\left(\psi^h, \varphi^h, \mu^h, y_{AE}^h, y_{EM}^h\right)$ cannot exceed the total value of initial endowment. Note that when the term $\sum_{j=1}^{J} q_j(\psi_j^h - \varphi_j^h) \geq 0$, agent h is a net buyer of financial claims and effectively a lender. When $\sum_{j=1}^{J} q_j(\psi_j^h - \varphi_j^h) \leq 0$, agent h is a net issuer/seller of financial claims and effectively a borrower.

Equation (2) represents the budget constraint in state "s" of period 1, which says that the expenditure on consumption cannot exceed the value of consumption endowment + payoff from $y_{AM}^h \; and \; y_{EM}^h$ + net delivery of financial contracts + payoff from riskless assets − tax obligation.

Equation (3) represents the collateral constraint, which states that agent h is required to hold sufficient Y_{AE}^h as collateral to back his total issuance of financial claims.

Agent maximization in the EM is the same as in the AE, except that EM agents are subject to capital control and macro-prudential restriction in their purchases of AE assets. Raising τ [13] is analogous to tightening capital control, while raising k is analogous to tightening the collateral requirement, and vice versa.

E. Agent Maximization for the Emerging Markets (EM)

$$\max_{c^{h^*} \geq 0, \psi^{h^*} \geq 0, \varphi^{h^*} \geq 0, \mu^{h^*} \geq 0, y_H^{h^*} \geq 0, y_F^{h^*} \geq 0} u^{h^*}\left(c^{h^*}\right) \quad s.t.$$

capital control parameter

$$p_0 c_0^{h^*} + \sum_{j=1}^{J} q_j(\psi_j^{h^*} - \varphi_j^{h^*}) + \pi_{AE}(1 + \tau) y_{AE}^{h^*} + \pi_{EM} y_{EM}^{h^*} + (1+i)^{-1} \mu^{h^*} \leq p_0 e_{C_0}^{h^*} + \pi_{EM} e_{Y_{EM}}^{h^*} + (1+i)^{-1} e_B^{h^*}, \quad (4)$$

$$p_s c_s^{h^*} \leq p_s\left(e_{C_s}^{h^*} + y_{AE}^{h^*} d_s^{AE} + y_{EM}^{h^*} d_s^{EM}\right) + \sum_{j=1}^{J} (\psi_j^{h^*} - \varphi_j^{h^*}) \min\{j, p_s d_s^{AE}\} + \mu^{h^*} - \theta^{h^*} \mu, \; \forall s \in \{U, D\} \quad (5)$$

[13] For simplicity, capital control here is only imposed on capital outflow from EMs. It can be similarly imposed on capital inflow to EMs and generates similar results. In fact, many EMs resort to capital controls asymmetrically.

macro-prudential parameter

$$y_{AE}^{h^*} \geq k * \sum_{j=1}^{J} \varphi_j^{h^*}, \tag{6}$$

F. **Definition of Equilibrium**

Given endowment and monetary specification:

$(e_{C_0}^{h}, e_{Y_{AE}}^{h}, e_{B}^{h}, \{e_{C_s}^{h}\}_{s\in\{U,D\}})$ for $h \in \mathcal{H}$;
$(e_{C_0}^{h^*}, e_{Y_{EM}}^{h^*}, e_{B}^{h^*}, \{e_{C_s}^{h^*}\}_{s\in\{U,D\}})$ for $h^* \in \mathcal{H}^*$;
and $(i, b^{CB}, y_{AE}^{CB}, \{p_s\}_{s\in\{U,D\}})$,

an equilibrium for the economy is a vector:

$$[(\bar{c}, \bar{\psi}, \bar{\varphi}, \bar{\mu}, \overline{y_{AE}}, \overline{y_{EM}}); (\overline{c^*}, \overline{\psi^*}, \overline{\varphi^*}, \overline{\mu^*}, \overline{y_{AE}^*}, \overline{y_{EM}^*}); (\bar{p}, \bar{q}, \bar{\pi})]$$

that is consistent with the monetary specification and in addition satisfies the following:

(i) Given prices $(\bar{p}, \bar{q})$ and interest rates (i) , $(\bar{c}, \bar{\psi}, \bar{\varphi}, \bar{\mu}, \overline{y_{AE}}, \overline{y_{EM}})$ and $(\overline{c^*}, \overline{\psi^*}, \overline{\varphi^*}, \overline{\mu^*}, \overline{y_{AE}^*}, \overline{y_{EM}^*})$ solves AE and EM agents' maximization problem respectively.

(ii) $\sum_{h=1}^{\mathcal{H}} \overline{c_0^h} + \sum_{h=1}^{\mathcal{H}^*} \overline{c_0^{h^*}} = \sum_{h=1}^{\mathcal{H}} e_{C_0}^{h} + \sum_{h=1}^{\mathcal{H}^*} e_{C_0}^{h^*}$

(iii) $\sum_{h=1}^{\mathcal{H}} \overline{c_s^h} + \sum_{h=1}^{\mathcal{H}^*} \overline{c_s^{h^*}} = \sum_{h=1}^{\mathcal{H}} e_{C_s}^{h} + \sum_{h=1}^{\mathcal{H}^*} e_{C_s}^{h} + \sum_{h=1}^{\mathcal{H}} e_{Y_{AE}}^{h} d_s^{AE} + \sum_{h=1}^{\mathcal{H}^*} e_{Y_{EM}}^{h^*} d_s^{EM}\ \forall s \in \{U, D\}$;

(iv) $\sum_{h=1}^{\mathcal{H}} \overline{y_{AE}^h} + y_{AE}^{CB} + \sum_{h^*=1}^{\mathcal{H}^*} \overline{y_{AE}^{h^*}} = \sum_{h=1}^{\mathcal{H}} e_{Y_{AE}}^{h}$;

(v) $\sum_{h=1}^{\mathcal{H}} \overline{y_{EM}^h} + \sum_{h^*=1}^{\mathcal{H}^*} \overline{y_{EM}^{h^*}} = \sum_{h=1}^{\mathcal{H}} e_{Y_{EM}}^{h^*}$;

(vi) $\sum_{h=1}^{\mathcal{H}} (\psi_j^h - \varphi_j^h) + \sum_{h^*=1}^{\mathcal{H}^*} (\psi_j^{h^*} - \varphi_j^{h^*}) = 0\ \forall j \in J$;

(vii) $\sum_{h=1}^{\mathcal{H}} \overline{\mu^h} = \mu \equiv \sum_{h=1}^{\mathcal{H}} e_B^h + (1+i)\pi_{AE} y_{AE}^{CB}$;

(viii) $\sum_{h^*=1}^{\mathcal{H}^*} \overline{\mu^{h^*}} = \mu^* \equiv \sum_{h^*=1}^{\mathcal{H}^*} e_B^{h^*}$ - $(1+i)\sum_{h^*=1}^{\mathcal{H}^*} \tau \pi_{AE} y_{AE}^{h^*}$

The model can be solved numerically as a system of non-linear equations. See Geanakoplos and Wang (2017) for further details regarding the solution of the model.

IV. QUANTITATIVE RESULTS: SIMULATION AND EVIDENCE

This section presents our model's major quantitative results. We first show that with the introduction of QE, the AE central bank is able to directly affect the long-term interest rate (i.e., π_{AE}), despite keeping the short-term interest rate unchanged.

Next, we show that with the Y_{AE} holdings on its balance sheet, the AE central bank is able to deploy two dimensions of monetary policy during QE exit: (a) adjustment of the short-term policy rate and (b) adjustment of balance sheet holdings. We show that these dimensions of monetary policy in the AE differ in their financial spillovers to the EM. In the case of policy rate adjustment in the AE, the EM can counter some of the potential financial spillovers by simply aligning its short-term policy rate with that of the AE central bank. However, in the case of a balance sheet adjustment (e.g., unwind) in the AE, there is no such simple policy re-alignment for the EM.

Finally, we examine how policy options such as *capital controls* and *macro-prudential tools* might be used by the EM to narrow the *changes* in long-term yield gaps, and thereby mitigate cross-border financial spillovers as a result of the AE central bank's balance sheet unwind.

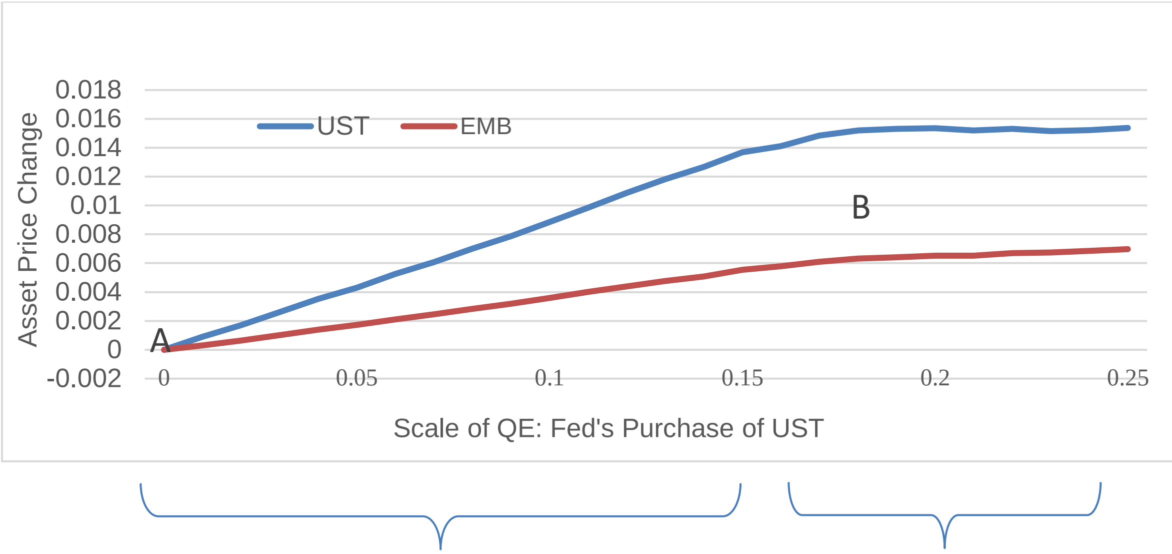
A. The Model's Results

Figure 2 illustrates how QE affects the prices of UST and EMB in our model.[14] As the Federal Reserve starts purchasing UST, it creates excess demand for UST and initially results in its price increase relative to EMB. Note that changes in the price gap between UST and EMB reflect the changing "collateral premium" demanded by the market and reflects market tightness for collateral. The widening price gap between UST and EMB from point A to point B reflects tighter collateral constraints in the global market as a result of QE.

While global demand for collateral and collateral-backed financial claims supports the collateral value of UST, large enough QE results in a widening of international spread and a subsequent portfolio shift by AE agents toward higher-return EMB (beyond point B). The outflow of agents from the AE to the EM gives rise to the "kink" in the price of UST (blue line)—i.e., a temporary decline in the price of UST relative to that of EMB. (See Geanakoplos and Wang (2017) for the detailed mechanisms behind the non-monotonicity of asset price movements.)

[14] The X-axis indicates the share of Y_{AE} acquired by the AE central bank through QE.

Figure 2. Effects of QE on Asset Prices



QE is initially effective in raising the prices of both UST and EMB. (i.e., lowering bond yield).

Marginal impact of continued QE weakens: US asset price declines relative to EM; this coincides with a surge of U.S. capital to "search for yield" in the EM.

Source: Authors' model estimate

An important policy implication from Figure 2 is that even when the AE's short-term policy rate is kept unchanged, QE can independently affect long-term yield gaps between the two countries.[15] Without a policy response from the EM, these changes in long-term yield gaps would translate into cross-border flows. Traditionally, the EM could counter some of the potential financial spillovers from the AE by aligning its short-term policy rate with that of the AE central bank. However, there is no such simple policy re-alignment by which the EM can mitigate changes in long-term yield gaps as a result of the AE central bank's balance sheet adjustment.

The quantitative results above illustrate the effects of QE in the model. Our next objective is to study the unwind of QE and its implications for the EM. More specifically, we illustrate how a policy rate hike differs from balance sheet unwind.

We first show how asset prices respond to an increase in the short-term policy rate in the AE. (Note that in our model, the AE central bank controls the short-term policy rate by adjusting its interest payment on central bank reserves.) As shown in Figure 3a, an increase in the short-term interest rate leads to a linear decline in the price of UST; this is because at the margin, the price of UST is primarily driven by leveraged investors who fund their purchase with collateralized borrowing.[16] Thus, a rise in the short-term interest rate results in higher borrowing cost for leveraged investors, which in turn lowers the price of UST linearly. In our model, the EM aligns its short-term policy rate with the AE by default (since we assume a

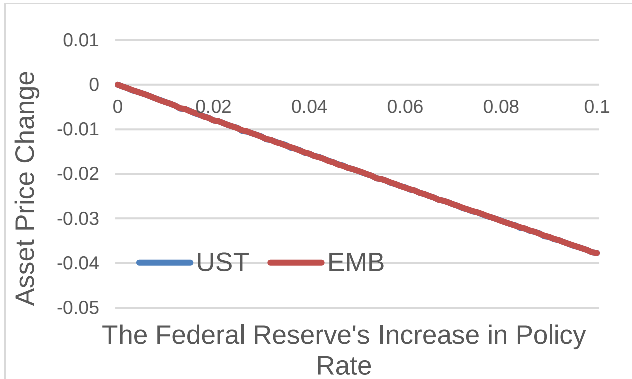
[15] Changes in the price gap between EMB and UST (i.e., $\pi_{EM} - \pi_{AE}$) are analogous to the changes in long-term yield gaps.

[16] Such investors include financial institutions that profit from maturity transformation, and other investors who borrow at the short-term rate and invest to earn the long-term term premium.

fixed exchange rate, as noted in Section III).[17] Figure 3a suggests that the EM's simple policy alignment with the AE would ensure that the price change in EMB mimics that of the UST.

Figure 3. Policy Rate Change vs. Balance Sheet Unwind

Figure 3a. Effects of QE Exit: Interest Rate Hike
(Blue Line Overlaps with Red Line)

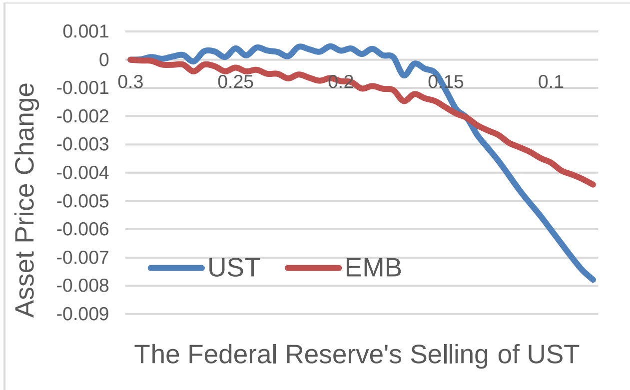


Source: Authors' model estimates.

Next, in Figure 3b we illustrate how asset prices might change if the AE central bank unwinds its balance sheet (i.e., by releasing UST back to the market) while keeping the short-term policy rate unchanged. In this case, it is worth noting that the Federal Reserve's release of UST back to the market does not result in an immediate decline in the price of UST. Instead, it remains robust initially as AE agents that invest in EM return to absorb the increased supply of UST (at higher yields) released by the AE central bank. This type of international portfolio shift is accompanied by a slight decline in the price of EMB. The key difference between an interest rate hike and balance sheet adjustment is that the former only affects the asset price of UST, whereas the latter also alters the supply of UST.

[17] As mentioned earlier, this is for simplicity since our focus is on the effects of unconventional monetary policy.

Figure 3b. Effects of QE Exit: Balance Sheet Unwind



Source: Authors' model estimates.

Continued supply of UST eventually dominates the demand from returning investors; this may lead to decline in the price of UST. The falling price of UST, meanwhile, may expedite the decline in the price of EMB. In the case in which the AE central bank unwinds its balance sheet, there is no simple policy response by which the price changes in UST and EMB are aligned. Below, we show how capital flow management and macro-prudential policies might be helpful in mitigating this kind of financial spillover.

Before we demonstrate how capital control and macro-prudential policy might help complement the EM's policy choices in response to the AE's balance-sheet unwind, it is helpful to discuss how the above results relate to the impacts of monetary policy on collateralized funding markets in practice.

B. Uncertainty about and Risks to the Value of Collateral

Our model suggests that a balance sheet adjustment by the Fed can directly influence the price of UST despite keeping the short-term policy rate unchanged. Given that UST is among the most prevalent collateral in the collateralized funding market, any increase in the uncertainty or risks associated with the value of UST (collateral) can percolate through to the short-term interest rate in the collateralized funding market. For instance, if there are increased risks to the value of collateral (e.g., due to potential balance sheet adjustment by the Fed), lenders may demand a higher interest rate (or higher haircut) to compensate for the increased probability of default on collateralized contracts. Therefore, the Federal Reserve's impact at the long-end of the yield curve can also transmit to the short-end via such a collateral risk channel. Increased risks to, or uncertainty about the value of collateral as a result of QE unwind will likely have significant impacts on the collateralized funding market.

C. Market Plumbing

Impacts at the long-end of the yield curve (due to a balance sheet adjustment) can also percolate through to the short-term market rate through market mechanisms, as Singh (2015) emphasizes. For instance, once the Federal Reserve's balance sheet unwinds and a 10 year UST is released to the market, it may not continue to exist simply as a 10-year bond only—

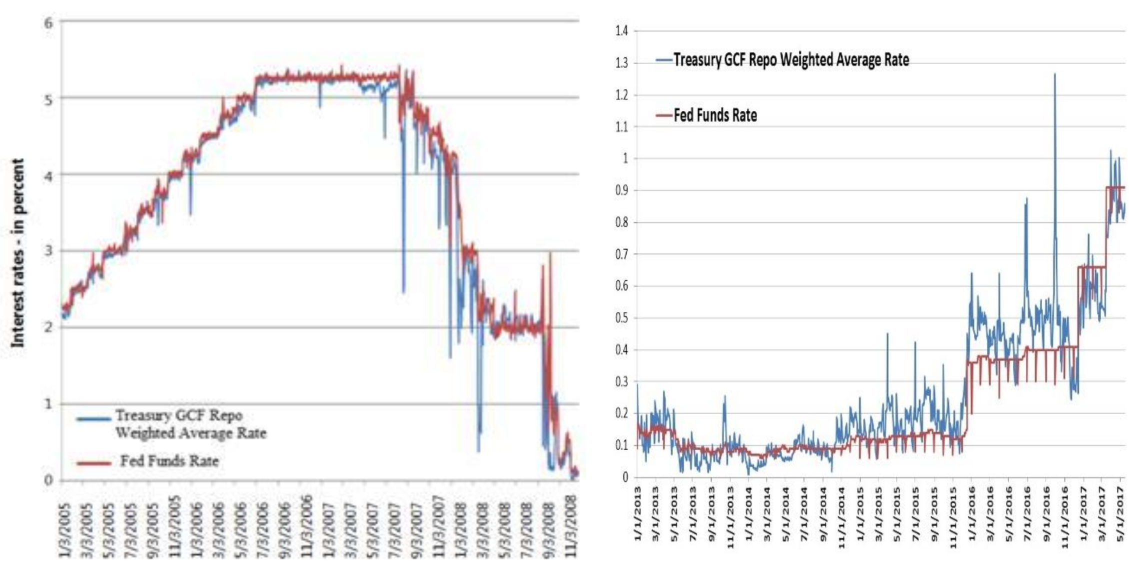
the market could transform it into a one-month repo, a one-year repo, a securities-lending transaction that has no defined tenor, or a margin toward an OTC derivative position; it could also be used for funding via rehypothecation to a prime broker.

Collateral reuse/velocity is exogenous to central banks. To control reuse, central banks may resort to “reverse repo program (RRP)-type structures” that keep collateral velocity muted (Box 1). Furthermore, when long-term UST are structured and reused as short-term securities in the market, changes in long-term treasury yield will indirectly translate into changes in the short-term market interest rate. Such maturity transformation activities are, in fact, very common in the private market.

Bilateral pledged collateral market rates, although unobservable, do pass-through to other interest rates, and thus to the real economy. When the market plumbing (or the money/collateral nexus) works, the general collateral finance (GCF) rate is a reliable proxy for bilateral repo rates. Without plumbing, the GCF rate would have little information content. Before the Lehman-crisis, the federal funds (FF) rate remained within +/−3 basis points of the GCF rate, except for quarterly-ending dates that straddled inventory, regulatory, and reporting aspects. After liftoff, it is interesting to note that the FF rate is not line with the GCF rate, as was the case pre-Lehman (see Figure 4).

Figure 4. Policy Rates and Market Short-term Rates
Pre-Lehman vs. Present

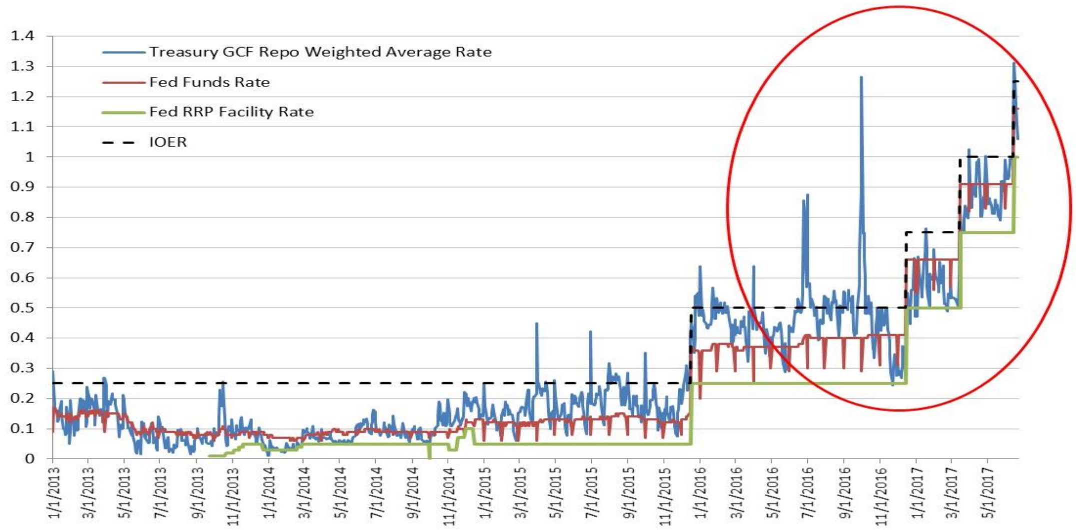
(First panel: 2005–08; second panel: 2011–17)



Sources: Depository Trust and Clearing Corporation (DTCC); Federal Reserve; and Bloomberg.

Due to QE, the Federal Reserve’s balance sheet increased from roughly $1 trillion (end 2007) to more than $4 trillion by end 2014, owing mainly to about $3.4 trillion of asset purchases that sit on its asset side. The approximate corresponding entry was excess reserves of $2.9 trillion on the liabilities side; these are the deposits of nonbanks (that sold assets to the Federal Reserve) at banks, that then placed them as deposits at the Fed. From October 8, 2008 to December 16, 2015, the Federal Reserve offered banks 25 basis points per annum for their deposits (including excess deposits over the required reserves), but paid zero interest on deposits from nonbanks, especially GSEs.[18] Since liftoff, the Federal Reserve is now offering 125 basis points to banks or, interest on excess reserves (IOER), represented by the dashed line in Figure 5, and 100 basis points to eligible nonbanks via the reverse repo program (shown by the red line in Figure 5).

Figure 5. After Fed Liftoff: Spread between Repo Rate and Fed Funds has Increased



Source: Bloomberg and DTCC

The wedge between GCF and FF is relevant to policy makers, who have two choices: (a) continue to focus on the policy rate, where volumes are shrinking to well below $100 billion/day, and the rate itself is supported by the RRP floor and IOER ceiling; neither existed prior to 2008; or (b) focus on the GCF, which is an approximation of market driven secured funding rate(s) (which we do not observe), and thus is relevant for cross-border pledged collateral flows of almost $6 trillion (see Box 2).

Prior to the Lehman crisis, a general *shortage of reserves* was addressed by the Federal Reserve's interventions from repo operations (via the relatively small "system open market account" (SOMA) at the New York Fed) so that the Fed Funds rate would remain in alignment with the collateral rate (i.e., the GCF rate). Now, there is an *excess of reserves* with the banking system, so changes in the Fed Funds rate are not possible (see Box 1 and Box 2).[19] Figure 5 suggests a shift from a market in which secured GCF rates were in sync with policy rates, to a situation in which GCF is permanently higher. (Singh 2017a) suggests

[18] To be precise, the total UST and MBS held by the Federal Reserve as of April 22, 2014, was $4.2 trillion, of which $750 billion were held as of end 2007. Excess reserves as of April 22, 2014, were $2.9 trillion, essentially all of which was added after end 2007.

[19] Lawrence Summers' remarks at the Annual IMF Research Conference (November, 2016) suggest that money, in the Friedman sense, no longer plays a significant role in macroeconomics; He also mentioned that money is a hot potato and everyone tries to get rid of the hot potato, and money is equal to floating rate public sector debt.

that this is because deposits in the banking system (or excess reserves at the Fed) leave limited balance sheet space for market plumbing.

Simon Potter, who heads the markets group at the New York Fed, remarked in his February 2016 speech on the lift-off (which was accompanied by increasing the RRP to about $2 trillion):

> *"One might also worry that money market rates might not move together as rates rise, meaning that, for example, a disconnect might emerge between secured and unsecured rates, or between overnight and term instruments. Either situation could result in impaired transmission of monetary policy into broad financial conditions."*

Box 1. Fed's Liftoff and the Triparty Repo

The bilateral pledged collateral market does not include Triparty Repo (TPR) related collateral. The TPR market provides the banks with cash on a secured basis, with the collateral being posted to cash lenders (e.g., money market funds) through Bank of New York, the clearing bank. The operational structure of the RRP facility puts practical restrictions on the reuse of collateral outside the Triparty system. Collateral can only be used in a Triparty repo liability. So a firm that acts as a dealer in the Triparty system, such as Goldman Sachs and Co., could have as an asset a Fed RRP and as a liability a Triparty repo with a customer. Members of the Government Securities Division (GSD) of the Depository Trust and Clearing Corporation (DTCC) can reuse the collateral within the General Collateral Finance (GCF) Triparty system. The important point is that reuse of collateral can only end in a Triparty repo; it can have no other use outside this system. The "released" collateral from the RRP remains as asset on the Fed's balance sheet and within the Triparty system. (See Box 2 for discussion on the bilateral pledged collateral market that is outside the Triparty system.)

The constraint noted above implies that, regardless of the size of the bids on RRP, the Fed's balance sheet will not decrease as a result of this form of "use" of excess reserves. The liftoff was accompanied by an increase in the RRP size of about $2 trillion. Even if used fully, this collateral will remain on the Fed's balance sheet and not be freely available to the financial system. Within the present Triparty structure, none of this collateral can be used to post at central clearinghouses, in the bilateral derivatives markets, in the bilateral repo market, or delivered against short positions. Most discussions of Triparty repo are silent on the point that RRP is not a form of "reserves drainage": i.e., rather than reducing the size of the Fed's balance sheet, RRP changes the composition of the liability side (i.e. an "accounting drainage").[1/]

There is a key difference between selling assets from the Fed's balance sheet in order to shrink the balance sheet, and reshuffling Fed liabilities between line items called "reserve balances," and other items on the liability side such as "reverse repurchase agreements" (or RRPs). Selling assets allows those assets to move directly to their final holder—i.e., they no longer belong to the Fed and the balance sheet reduces. The new holder of the asset (e.g., an insurance company or a hedge fund) can reuse the asset without any restriction. In contrast, if the asset moves from Fed's liability side line item "reserve balances" to another item on the liability side "reverse repurchase agreements"; the holder under the RRP terms cannot reuse it, and can only count it as HQLA, or high quality liquid asset, for regulatory reasons.

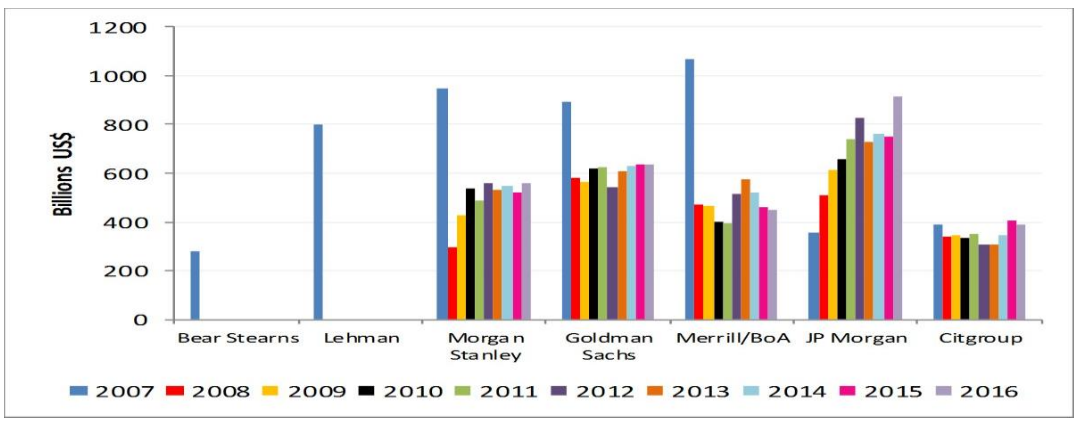
[1]/ This observation about changing the composition of liabilities also has been made in a speech by Fed vice-president Potter (2015) http://www.ny.frb.org/newsevents/speeches/2015/pot150415.html (footnote 2).

Box 2. The Financial Plumbing: The Pledged Collateral (and its Reuse) Market

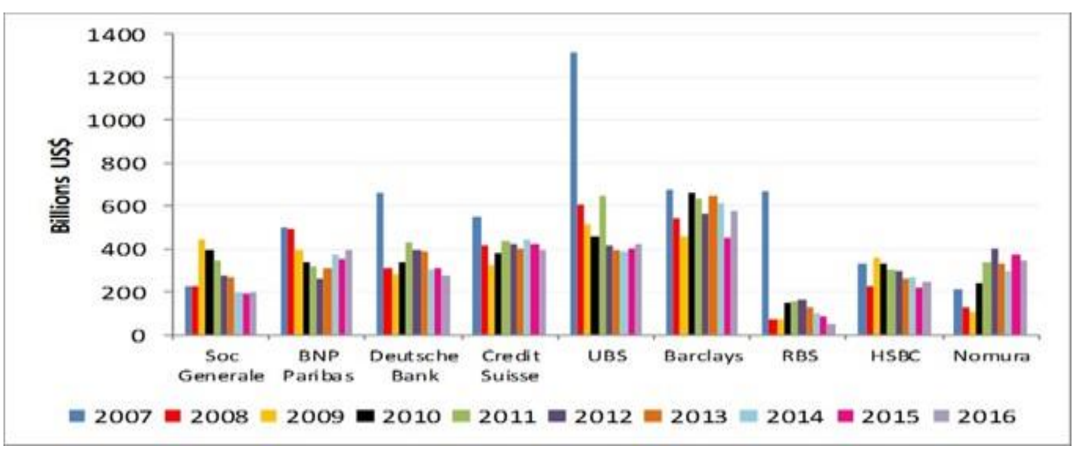
Financial agents that settle daily margins may choose to post cash or securities, depending on which is "cheapest to deliver" from their perspective. These settlements form the core of the financial plumbing in markets that require debits/credits to be settled continuously. These securities are generally received by the collateral desks of the banks not only via reverse-repo but also from securities borrowing, prime brokerage agreements, and over-the-counter (OTC) derivative positions.

The fair value of securities received as collateral that is permitted to be sold or re-pledged by global banks was approximately $10 trillion in 2007 but has declined in recent years to about $6 trillion (see figures below). Securities that are pledged, at mark to market values, may be bonds or equities, are cash-equivalent from a legal perspective (i.e., with title transfer) and do not have to be AAA/AA rated. Following the methodology of Singh (2011), and incorporating the amount of "source collateral," the collateral reuse rate (or "collateral velocity") can be approximated; this rate has declined markedly, from about three as of end 2007 to about 1.8 as of end 2016. The decline in the reuse rate adversely impacts financial lubrication in the market. Central banks should be cognizant of the collateral reuse rate in the bilateral pledged collateral market, along with money metrics, to gauge the short-term rate environment. Otherwise, unwind of central bank balance sheets (i.e. release of good collateral), along with reuse rate, can result in short-term market rates having a wedge with policy rates. For effective monetary policy transmission, market rates need to move in tandem with policy rates.

Pledged Collateral Received by U.S. Banks (2007–16)



Pledged Collateral Received by European Banks and Nomura (2007–16)



Sources: Hand-picked data by authors from annual reports; see also Singh (2011).

D. **Policy Options for EMs—Capital Control vs. Macro-prudential Policy**

Although some economists (e.g., Bernanke (2015) and Greenwood, Hanson and Stein (2016)) argue that AE central banks can maintain their large balance sheet(s) and there may be no need to unwind these, it may be prudent for EMs to be equipped with the necessary tools in case the economy they are anchored to decides to unwind its balance sheet as part of its monetary policy.

As background, the Federal Reserve never remunerated excess reserves prior to the Lehman demise but began doing so on October 8, 2008, after changing the law. As the policy rate moves higher, the Federal Reserve's remuneration on IOER paid to banks will be substantial and will likely raise economic and political debates.[20] Furthermore, if policy makers believe that it is necessary for GCF to be in sync with FF, there must be a shortage of reserves in the banking system so that GCF can increase the supply of reserves to the banking system—a distant scenario from the over $2 trillion of excess reserves presently with the banking system. Only a genuine balance sheet unwind will reduce excess reserves. Singh (2017b) argues that excess reserves and good collateral are different, and how dealer balance sheet space (due to an unwind of Fed's balance sheet) may increase collateral reuse, and have an easing effect. Thus, balance sheet reductions and policy rate hikes are not equivalent.

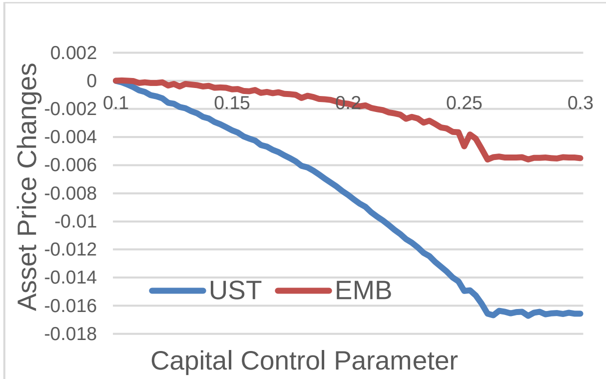
Figure 6a, which depicts the resulting asset price changes as the EM increases its capital control parameter, shows that the EM's capital control puts downward pressure on the price of UST relative to that of EMB. In other words, capital control in the EM is effective for strengthening the price of EMB relative to that of UST.

Similarly, Figure 6b illustrates how asset prices respond to a tightening of macroprudential policy in the EM. In our model, macro-prudential policy takes the form of an adjustment of the collateral requirement on agents. By raising the collateral requirement in the EM, leveraged investors are discouraged from purchasing of UST; this puts downward pressure on the price of UST relative to that of EMB.

[20] The arithmetic of remunerating excess reserves is quite different when policy rates are increasing; this rate cycle is envisaged to end lower than the past cycles, but consensus expects a 3% target (300 bps on $2.5 trillion, at present, is $75 billion; 25 bps on $3 trillion, a couple of years ago, was $7.5 billion).

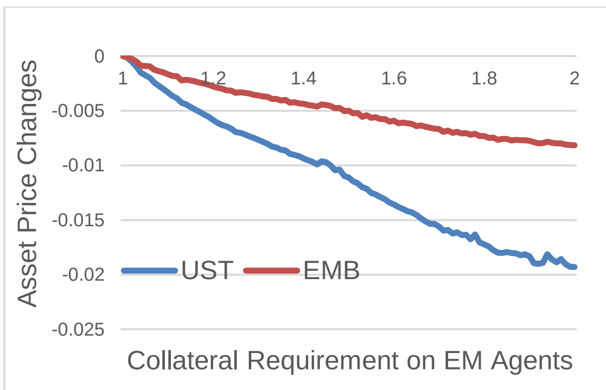
Figure 6. Raising Capital Controls and the Macro-Prudential Requirement Strengthens Relative Asset Price in EM

Figure 6a. Effects of EM’s Capital Control



Source: Authors’ model estimates.

Figure 6b. Effects of EM's Macro-Prudential Policy

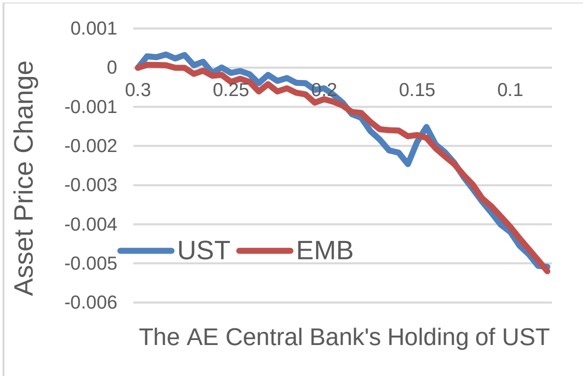


Source: Authors’ model estimates.

As we can see, both capital control and macroprudential policy in the EM strengthen the relative price of EMB against UST. We show that these two policy tools can be used to narrow the price gaps (as shown in Figure 3b) between UST and EMB.

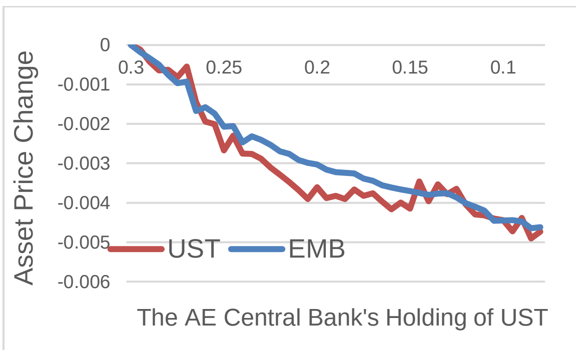
Figure 7. Capital Controls and Macro-Prudential Response to Balance Sheet Unwind

Figure 7a. Varying Capital Control in Response to Balance Sheet Unwind



Source: Authors' model estimates.

Figure 7b. Varying Macro-prudential Policy in Response to Balance Sheet Unwind



Source: Authors' model estimates.

We vary the capital control parameter to narrow the gap (in Figure 3b) between the price changes in UST and EMB. Figure 7a suggests that by varying the intensity of capital control in the EM, it is possible to mitigate to a large degree the price impact resulting from the AE central bank's balance sheet unwind. We adjust the capital control parameter so that it is positively correlated with the wedge (in Figure 3b) created by the AE central bank's balance sheet unwind; the capital control parameter is high (tightening) when the price gap between UST and EMB widens. Similarly, we show that macro-prudential policy can be implemented in a way that counteracts most of the relative price effects of the Fed's balance sheet unwind, as shown in Figure 7b.

V. Conclusion

Going forward, several AE central banks will be able to exploit two major dimensions of monetary policy: the short-term policy rate and balance sheet adjustment. As demonstrated by our simple model, this allows for effective and independent control over both short-term and long-term interest rates. EMs that peg to AEs may need to assess their policy framework and complement their financial stability toolkit by including macroprudential and capital flow management measures. Furthermore, EMs will benefit from recognizing that balance sheet reductions and policy rate hikes may not be equivalent.

We also argue that understanding market signals such as repo rates is crucial, since these have traditionally guided the policy rate. A normal liftoff assumes that all short-term rates will move in line with the policy rate; otherwise, monetary policy transmission could be compromised. Although there has been no balance sheet unwind (see Box 1) since Fed's liftoff, the wedge between short-term rates is higher than in the past. When the Federal Reserve unwinds, this could lead to a larger wedge between short-term repo rates and policy rates, since collateral velocity (i.e., the reuse of collateral when released to the market) is not under the central banks' control.

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