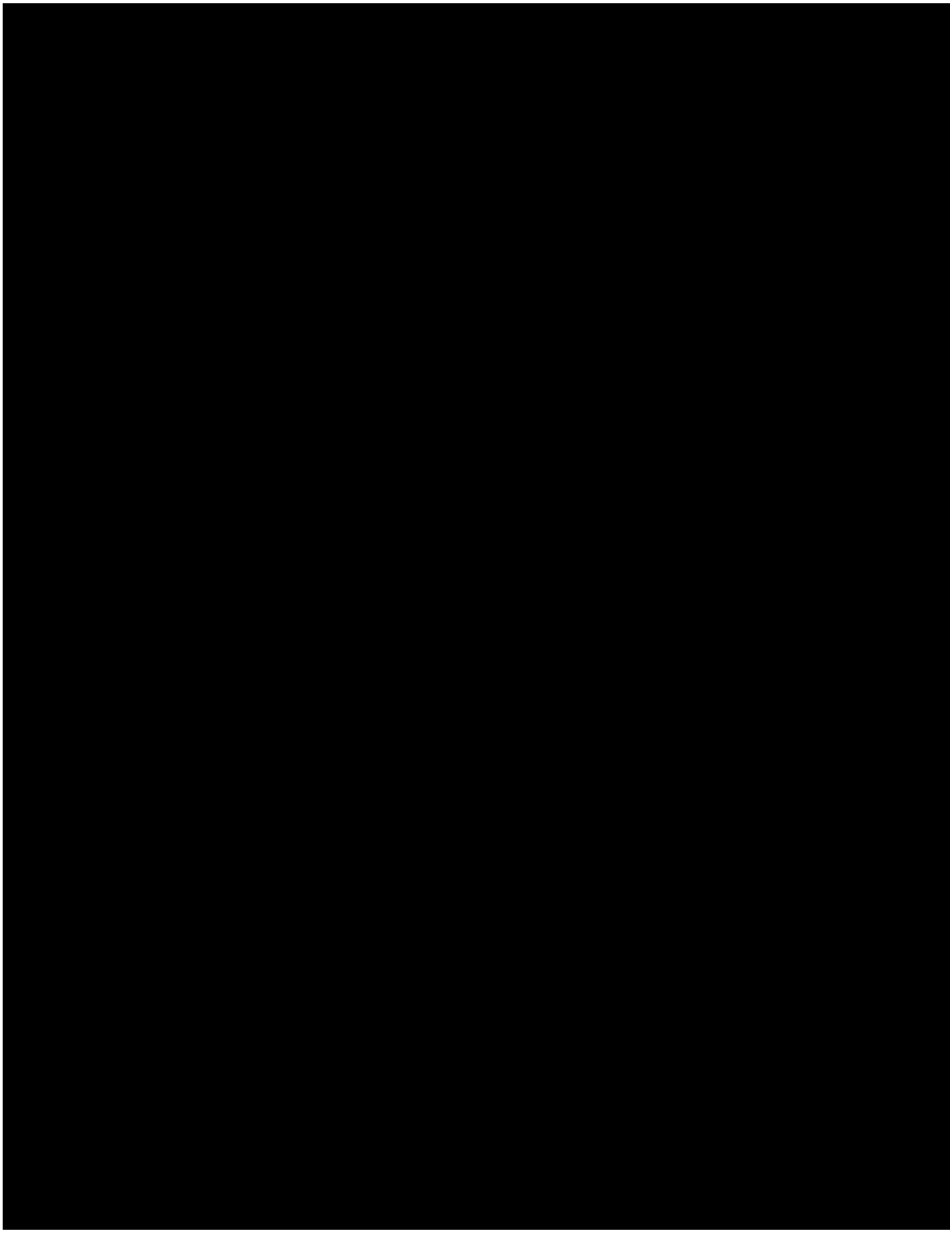

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Liquidity Management under Fixed Exchange Rate with Open Capital Account

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Abstract

This paper introduces a theoretical framework for liquidity management under fixed exchange rate arrangement, derived from the price-specie flow mechanism of David Hume. The framework highlights that the risk of short-term money market rates un-anchoring from the uncovered interest rate parity due to money and foreign exchange market frictions could jeopardize financial stability and market development. The paper then discusses operational solutions that stabilize money market rates close to the level implied by the Uncovered Interest Rate Parity (UIP). Liquidity management under fixed exchange rate with an open capital account presents specific challenges due to: (1) the larger liquidity shocks induced by foreign reserve swings that challenge the development of money markets; and (2) more complicated liquidity forecasts. The theoretical framework is empirically tested based on the estimate of "offset" coefficients for Denmark and Hong Kong SAR.

JEL Classification Numbers: E4, E5, E61, F31, F32.

Keywords: Fixed exchange rate regime, price-specie flow mechanism, uncovered interest rate parity, offset coefficients, monetary operations, autonomous factors, money and foreign exchange markets

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GLOSSARY

AREAER	Annual Report on Exchange Arrangements and Exchange Restrictions
BIR	Base Interest Rate
BNB	Bulgaria National Bank
BNG	Bulgarian Lev
CD	Certificate of Deposit
CDS	Credit Default Swap
CEMAC	Communauté Economique et Monétaire de l'Afrique Central
CiC	Currency in Circulation
DKK	Danish Krone
DNB	Danmarks Nationalbank
ECB	European Central Bank
EONIA	Euro OverNight Index Average
FARI	Financial Account Restrictiveness Index
FED	Federal Reserve
FX	Foreign Exchange
HIBOR	Hong Kong InterBank Offered Rate
HKD	Hong Kong Dollar
HKMA	Hong Kong Monetary Authority
HQLA	High Quality Liquid Assets
IMF	International Monetary Fund
ISIMP	Information System on Instruments of Monetary Policy
LA	Liquidity Absorption
LEONIA	LEv OverNight Index Average
LP	Liquidity Providing
MOID	Monetary Operations and Instruments Database
MPC	Monetary Policy Committee
NFA	Net Foreign Assets
OIN	Other Items Net
OMO	Open Market Operation
O/N	Overnight
R	Bank Reserves
RR	Reserve Requirements
SAIBOR	Saudi Arabia InterBank Offered Rate
SAMA	Saudi Arabia Monetary Authority
SF	Standing Facility
ToT	Terms-of-Trade
UAE	United Arab Emirates
UIP	Uncovered Interest Rate Parity
US	United States
USD	United States Dollar

I. INTRODUCTION

Most IMF members operate a fixed exchange rate arrangement. According to the Annual Report on Exchange Arrangements and Exchange Restrictions (AREAER 2016), 76 countries' exchange rate arrangements out of the then-192 IMF member countries belonged to the category of fixed exchange rates, including currency boards, conventional pegs, stabilized arrangements, and crawling pegs. In comparison, 71 IMF members operated market determined exchange rate arrangements, such as floating and free floating, representing the second largest group of exchange rate arrangements in 2016. The core target group of this paper are currency boards and pegs to a single currency (conventional pegs), though the paper also includes useful content for the broader group of fixed exchange rates.

The group of fixed exchange rate arrangements presents some heterogeneity. Many pegs are adopted by small open economies. However, fixed exchange rate arrangements include advanced economies, emerging markets, and low-income countries. Furthermore, commodity exporters with a low level of economic diversification also make a significant share of this category. In addition, there is heterogeneity in the commitment to the fixed exchange rate, as some countries regularly recourse to devaluations. Currency boards represent the strongest commitment, with monetary policy constrained by the rule to issue local currency only in exchange for foreign currency. Currency boards usually have limited capital controls.

The academic literature proposes some criteria to explain the choice of exchange rate arrangement. The criteria suggest that pegged regimes will be easier to implement when the economy is small, trade integration is high, labor markets are flexible, fiscal policy is sound, and shocks are nominal in nature or symmetric with the anchor country. More synchronized business cycles and the absence of country-specific exogenous shocks increase the benefit of sharing the anchor country's monetary policy.

Following Mundell (1963), the optimal choice of exchange rate arrangement depends on the nature of shocks—whether real or nominal—and the degree of capital mobility. In an open economy with capital mobility, the floating exchange rate insulates against real shocks (for example, Terms-of-Trade [ToT] shock), while a fixed exchange rate can be adopted in case of nominal shocks (for example, shifts in money demand). The concept of optimal currency area was also used in the academic literature both for setting the criteria for establishing a monetary union and the choice of exchange rate arrangement (Bordo 2003). The criteria posed by Mundell (1961), Kenen (1969), and McKinnon (1963) to assess a region as an optimal currency area involved the symmetry of shocks in the member states, the degree of openness, the degree of labor mobility, and the ability to make fiscal transfers.

A distinct set of criteria underlying the choice of a fixed exchange rate arrangement is related to the importance of a credible nominal anchor: pegging to the currency of a country with low inflation is a pre-commitment to anchor inflation expectations. While an independent monetary policy may be beneficial for some members, credibly committing to low inflation policies may be challenging and costly in the absence of a strong institutional track record, sound liquidity management, and a developed financial system allowing interest rate transmission. Therefore, members may also consider policy criteria in their choice of exchange rate arrangement; they may adopt pegs even when many of the macroeconomic

criteria fail to apply, and when they choose to borrow the monetary policy credibility of another country, or when the institutional capacity to implement flexible exchange rate regimes is still undeveloped. Countries' actual regime choice may differ from what is suggested by the academic literature, depending on how countries address the tradeoffs they are facing. Some countries facing ToT shocks have fixed exchange rates.

This paper focuses on the challenges of implementing monetary policy under a fixed exchange rate arrangement. It assumes that the arrangement does not rely on capital controls or devaluations to mitigate the constraints that the fixed exchange rate imposes on monetary policy. For many fixed exchange rates, the overall monetary policy design and implementation is complicated by the lack of a clear framework addressing the implementation of monetary policy under a fixed exchange rate arrangement. This paper proposes a liquidity management framework under normal conditions for central banks adopting fixed exchange rate arrangements and operating under capital mobility. The framework is derived from the theoretical background (that is, a conceptual framework) that supports the practical implementation of an interest rate corridor for fixed exchange rates without capital controls.

Monetary policy implementation under a fixed exchange rate arrangement and open capital account has the objective of defending the peg and preserving financial stability. On one hand, monetary policy should ensure that interest rates (that is, short-term money market rates) are steered to the level that stabilizes capital flows, thereby reducing the need for extensive intervention in the foreign exchange (FX) market. On the other hand, liquidity management should also aim at reducing the impact of autonomous factor fluctuations on bank reserves. When not offset by the central bank monetary operations, autonomous factor fluctuations increase interest rate volatility that, on its turn, undermines market development and can endanger financial stability.

Managing liquidity under a fixed exchange rate arrangement presents additional challenges than under standard liquidity management frameworks. These include: (1) the forecast of autonomous factors in the face of sizeable current account and/or capital account shocks; (2) the calibration of open market operations (OMOs) based on autonomous factor forecasts; and (3) the sterilization of large liquidity shocks induced by ToT shocks or capital flows. Finally, fixed exchange rate arrangements face the additional challenge of currency speculation, especially at a time of anticipated devaluation or misalignment of the currency.

The rest of the paper is structured as follows: Section II presents a conceptual framework for liquidity management under a peg and open capital account; Section III addresses the practical challenges of liquidity management under a fixed exchange rate arrangement and discusses how to operationalize the conceptual framework; Section IV highlights the need of *offsetting* shocks (exogenous and liquidity shocks) under fixed exchange rate arrangements; and Section V concludes.

II. A Conceptual Framework for Liquidity Management under a Fixed Exchange Rate with Open Capital Account

A. The Price-Specie Flow Mechanism Revisited

The academic literature on *monetary dynamics* under a fixed exchange rate could be traced to the price-specie flow mechanism of David Hume (1752). Though the concept of *monetary policy* didn't exist at that time, Hume already discussed the monetary dynamics triggered by trade balance transactions under a fixed exchange rate arrangement: the Gold Standard. According to Hume, a country running a positive trade balance under the Gold Standard would see gold flowing into the country in the amount of the trade balance. Conversely, in a country with a negative trade balance, gold would flow out of the country in the amount of the trade balance. Consequently, in the absence of any *offsetting* actions by the central bank (for example, *sterilization*) and abstracting from velocity, the money supply would rise in a country with a positive trade balance and fall in a country with a negative trade balance.

Referring to what is nowadays known as an unsophisticated version of the quantity theory of money (that does not account for velocity), Hume already argued that inflation would rise in the countries where the quantity of money increases while deflation would occur in countries where the money supply decreases. Higher prices in the country with a positive trade balance would cause exports to decrease and imports to increase, thereby altering the trade balance back to its *neutral* position. Conversely, in the country with a negative trade balance, lower prices would cause exports to increase and imports to decrease, thereby increasing the trade balance toward its *neutral* position. In his essay "Of Money," Hume restricted his analysis to adjustments in a *closed economy* setup. In addition, Hume's price-specie flow mechanism is centered on the *supply side* of the money market and does not address the notion of demand for real money balances (Casarano 1998).

The spirit of the price-specie flow mechanism underpins the monetary approach to the balance of payment (Mundel 1968 and 1971, Johnson 1971 and 1972, and Frenkel and Johnson1976). Under a fixed exchange rate arrangement, the money supply moves to equilibrate the market for domestic goods and services, and monetary policy is directed at preserving the balance in external accounts. Under a flexible exchange rate arrangement, the exchange rate moves to correct external disequilibrium and monetary policy aims at the goal of internal stabilization (Mundell 1971). Yet today, modern (conventional) monetary policy is more about changing the policy rate than the supply of money. In addition, capital flows can be sensitive to central bank changes of their policy rates.

In this paper, we build on the price-specie flow mechanism and extend it to the liquidity management under fixed exchange rate with open capital account. First, we revisit Hume's theory and apply it to a country's entire balance of payments, including financial and capital accounts, in an *open economy* setup potentially facing current account and/or capital account shocks. Under such a framework, a surplus of FX in the FX market (for example, trade balance surplus) either results in sales of FX by banks to the central bank—which increases both the net foreign assets (NFA) and bank reserves (that is, banks' accounts at the central bank)—or capital outflows. Conversely, a shortage of FX either results in purchases of FX by banks that decrease bank reserves and the NFA, or capital inflows. On the other hand, in the

absence of central bank intervention in the money market, a decrease of bank reserves leads to an increase in domestic money market rates that can trigger capital inflows. Conversely, an increase of bank reserves leads to a decrease in money market rates that can trigger capital outflows.

Second, we assume that the money and FX markets, rather than the market of goods, are the first channel through which the price-specie flow mechanism operates. This allows us to transform *monetary dynamics* into *liquidity dynamics* captured by the fluctuations of bank reserves at the central bank (thereafter liquidity) and their effect on short-term interest rates (money market rates). In the money market equilibrium considered in the following subsections, we discuss bank reserves demand and supply rather than the broader money demand-money supply.

B. The Reserves Demand and Supply under a Fixed Exchange Rate

Under standard money market equilibrium models (*money demand-money supply models*), three main factors determine aggregate money demand: the price level, interest rate, and real income. In standard models, an interest rate increase causes a decrease in aggregate money demand because it incentivizes economic agents to invest money in interest-bearing instruments (bonds). The demand for money departs from the need of transaction, but also depends on the opportunity cost of holding money (deposits), that is, the opportunity cost of not storing it in interest-bearing assets. Higher interest rates incentivize economic agents to hold fewer deposits.

Following standard macroeconomic models, models of *reserve demand and supply* have assumed that the demand for bank reserves at the central bank is also downward sloping. Khan (2010), for example, explains that the demand for reserve and settlement balances at the Federal Reserve (Fed) is inversely related to the federal funds rate for two reasons: (1) higher interest rates cause the public to reduce their holdings of transaction deposits that are subject to reserve requirements and increase holdings of higher yielding non-transaction accounts that are not subject to reserve requirements; and (2) higher interest rates cause financial institutions to limit their holdings of excess reserves and settlement balances.

While we do not challenge this view, we assume that in the extreme scenario of no reserve requirements and stable autonomous factors, banks would still demand a minimum level of reserves to minimize the risk of settlement failures. Such demand for precautionary reserves is a function of money market liquidity, depth, and efficiency, as well as the payment system.

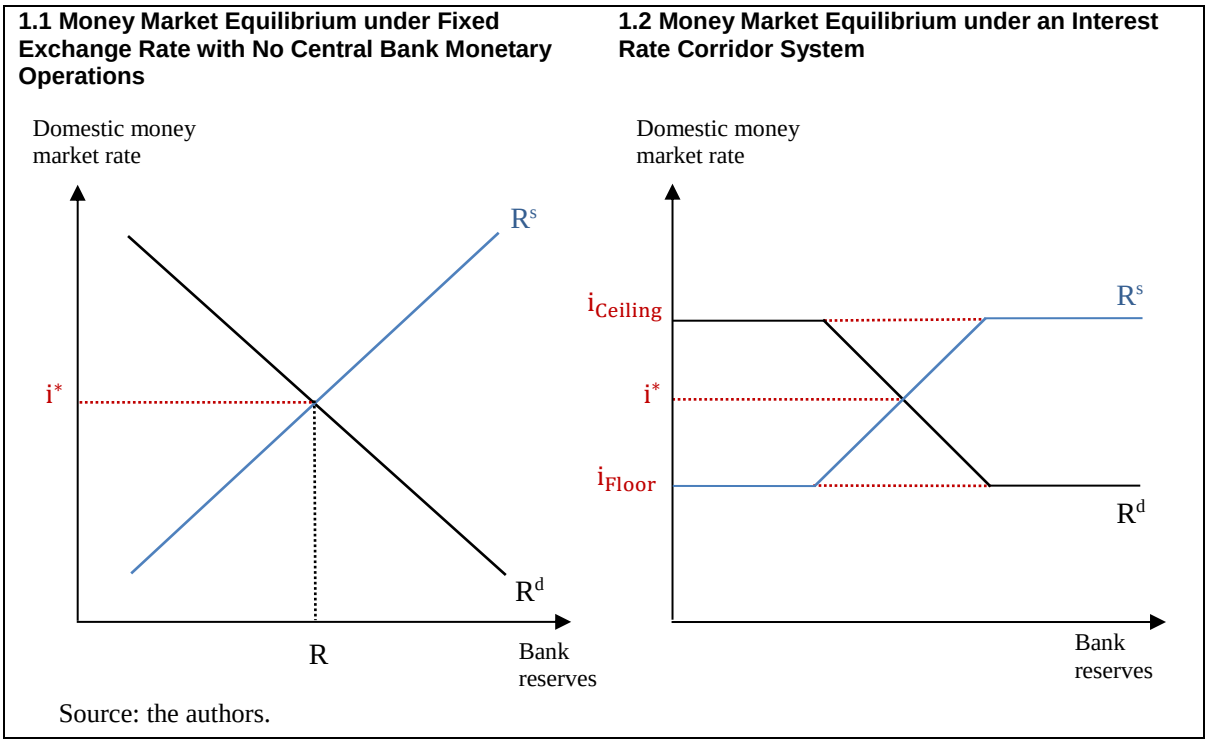
Under standard money market equilibrium models, the money supply is vertical, as set by the central bank. However, when assuming no central bank intervention in the money market, the reserve supply is a function of autonomous factors. Under a fixed exchange rate with open capital account, and in the absence of financial market frictions, the assumption of no central bank intervention in the money market implies that money supply is endogenous. When the government account at the central bank is low and stable and the increase in the currency in circulation (CiC) stable and small, the reserve supply becomes mainly a function of FX flows (that is, changes in the central bank NFA). In extreme cases, where the government account is stabilized close to zero (or no government account) and the CiC negligible compared to

other items of the central bank balance sheet, the NFA determine bank reserves supply in the absence of central bank monetary operations.

The change in the NFA on its turn reflects current account and capital account balances. Under a fixed exchange rate arrangement, capital flows are a function of the interest rate differential between the country that pegs its currency and the anchor currency. An increase in the interest rate of the country that pegs its currency attracts capital inflows, which increase both the supply of FX in the FX market and the supply of bank reserves, assuming no central bank intervention in the money market.

In the theoretical background of this paper, we assume an upward sloping (rather than vertical) reserve supply curve, meaning that an increase in the domestic money market rate attracts more FX and increases the NFA and bank reserves (Figure 1.1). However, in practice, the slope of the curve will depend on capital flow elasticity to the domestic money market rate. Capital flow elasticity is influenced by country-specific factors ("pull factors") as well as external factors, such as global liquidity and risk aversion ("push factors").[2] This elasticity can change over time. In Section IV of the paper, we show the change over time of the reserve supply curve for Denmark.

Figure 1. Theoretical Money Market Equilibrium



Source: the authors.

[2] Fratzscher (2011) and Cerutti and others (2015).

Under an interest rate corridor system (Figure 1.2), the overnight (O/N) standing credit and deposit facilities impose a firm ceiling and floor that limit money market rate fluctuations. When a bank is in liquidity deficit, it would have no reason to pay a rate higher than the ceiling to borrow funds O/N. And when a bank is in excess liquidity, it would have no reason to lend at a rate lower than the floor.

C. The Assumption of Seamless Liquidity Adjustment by Capital Flows

As a starting point, we consider that the central bank operates under a currency board rule and issues the local currency (CiC and bank reserves at the central bank) only against FX reserves. We assume that the government has an account at the central bank but that the central bank has no claims on the government. To further simplify the matter, banks are not subject to reserve requirements by the central bank. Though the central bank has FX standing facilities (FX interventions) under the fixed exchange rate arrangement,[3] we consider in this section that banks essentially rely on FX flows in their liquidity management.

Under the currency board arrangement, the central bank balance sheet is predominantly driven by its FX reserves, which represent the main item on the asset side (Figure 2). The liabilities are made of the CiC, the government account at the central bank, the balances that banks want to keep at the central bank (bank reserves), and other items (net). Figure 3 shows the balance sheet expansion of two currency boards, Bulgaria and Hong Kong SAR, driven by FX reserves accumulation. The Bulgaria currency board arrangement is presented in Box 1, and the Hong Kong SAR monetary policy framework and operations are discussed in more detail in Sections III.B. and IV.B.

Figure 2. Simplified Central Bank Balance Sheet under a Fixed Exchange Rate Arrangement

Assets	Liabilities
FX Reserves	Currency in Circulation
	Government Account
	Bank Reserves
	Other Items (Net)

Source: the authors.

Two sets of factors have an impact on bank reserves (banks' aggregated position at the central bank [R]):

- *Autonomous factors*: These are items on the central bank balance sheet that can influence bank reserves at the central bank without being under the direct control of the central bank. Main autonomous factors include CiC, the government account, and the NFA; and

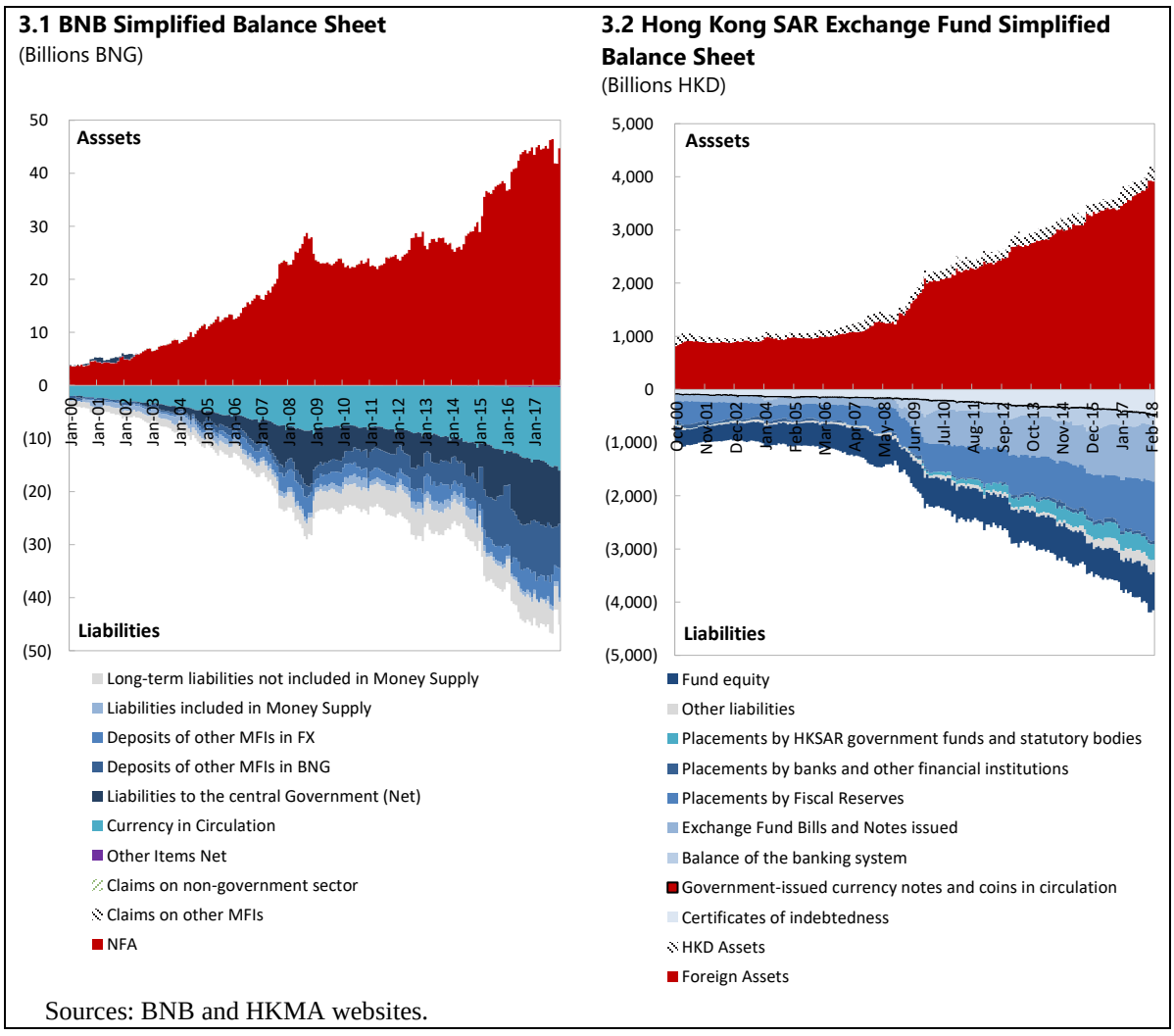
[3] The central bank buys and sells FX from commercial banks on demand and at a fixed exchange rate.

(continued…)

- *Banks' precautionary demand for reserves*, which is a function of settlement risk and the level of development and sophistication of the money markets[4].

Regarding markets, we initially consider a system with no frictions in the FX market: banks can buy and sell FX freely, and there is no cost attached to converting local currency in FX and conversely. Then we consider a system without country and counterparty risk. Local banks can borrow and lend FX under the same conditions as their foreign counterparties. In the local money market, they do not impose credit limits to their counterparties.

Figure 3. Bulgarian National Bank and Hong Kong SAR Exchange Fund Simplified Balance Sheets



Sources: BNB and HKMA websites.

[4] According to Khan (2010), in the 1990s, depository institutions in the United States sought ways to reduce their need to hold non-interest-bearing reserves through various financial innovations. They created new types of accounts—such as certificates of deposit (CDs), euro dollar borrowing, repurchase agreements, and sweep accounts—with features similar to deposit accounts but not subject to reserve requirements.

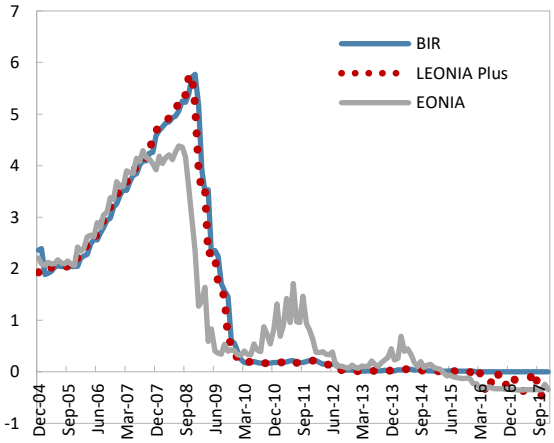
Box 1. Bulgaria Monetary Policy Framework and Exchange Rate Arrangement

The Bulgarian National Bank (BNB) adopted a currency board arrangement in 1997 as a stabilization policy in the aftermath of the 1996–97 financial crisis. The arrangement operates with a fixed exchange rate to the euro, and monetary policy has the ultimate objective of achieving price stability. The currency board arrangement was introduced in combination with increasing fiscal discipline, privatizations, and increased liberalization of the Bulgarian economy. The exchange rate arrangement provided the nominal anchor that the Bulgarian economy needed.

At the operational level, the only liquidity management instrument the BNB uses are reserve requirements and term deposits (Appendixes II, III, and IV). BNB, however, announced a reference interest rate called a base interest rate (BIR), using a methodology determined by its governing council.

Until January 28, 1997, the BIR was one of the BNB's monetary policy instruments. Since the introduction of the currency board on July 1, 1997, the BIR has been only a reference rate. Currently, the BIR, effective from the first day of each calendar month, equals the simple average of the values of the LEv OverNight Index Average (LEONIA) Plus for the business days of the previous calendar month (base period). LEONIA Plus is a reference rate of O/N deposit transactions in Bulgarian lev in the interbank market of all banks licensed by the BNB and branches of foreign banks in Bulgaria, which the BNB computes and publishes each business day (Figure 4).

Figure 4. BNB BIR and LEONIA Plus



Source: BNB website.

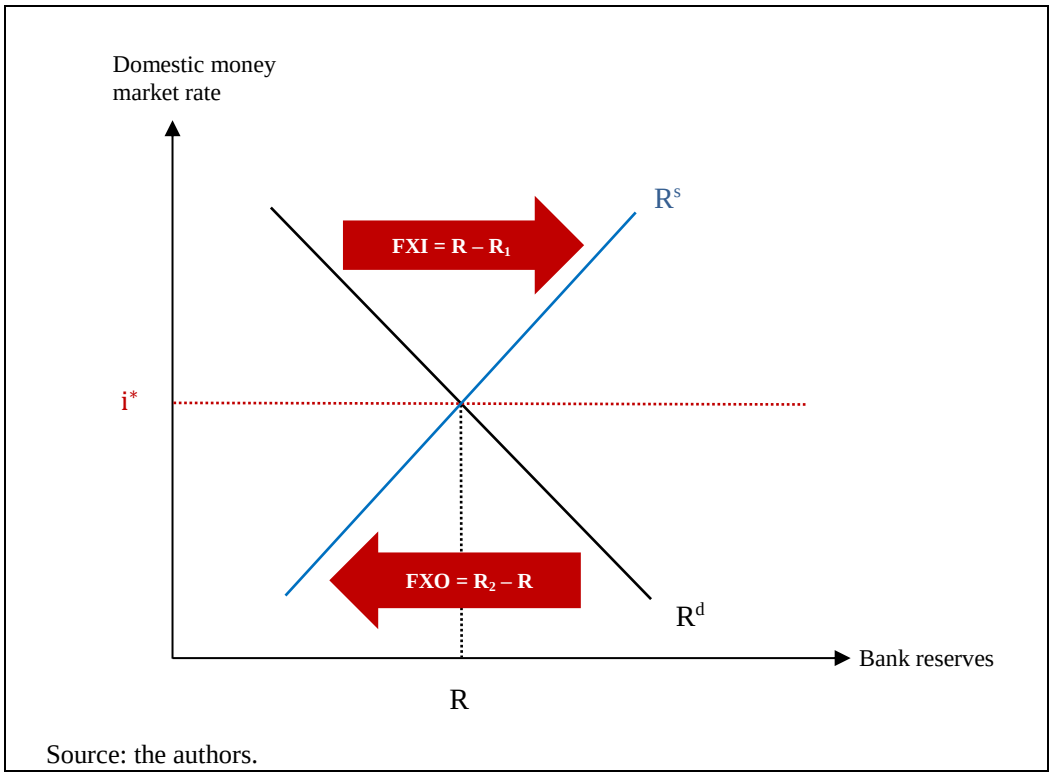
Sources: BNB website, Iskrov (2012), and https://dsbb.imf.org/sddsplus/dqaf-base/country/BGR/category/INR00.

Under these assumptions, any reserve shortage or surplus will be *offset* by capital flows. In well-functioning markets, short-term rates are expected to adequately respond to reserves in excess (or deficit) vis-à-vis banks' precautionary demand. Any deviation due to a change in autonomous factors will trigger the following adjustments (Figure 5):

- Any decrease in bank reserves at the central bank at a level R_1 below equilibrium ($R_1<R$) will lead to an increase in domestic short-term rates that immediately triggers FX inflows (FXI) that exactly *offset* the shortage, bringing the level of bank reserves back to R (FXI $=R-R_1$).

- Any increase of bank reserves at the central bank above equilibrium ($R_2>R$) will lead to an immediate decrease in short-term rates that immediately triggers FX outflows (FXO) that exactly *offset* the surplus bringing the level of bank reserves back to R (FXO = R_2-R).

Figure 5. Short-Term Interest Rate and FX Flows under a Fixed Exchange Rate with Open Capital Account and without Frictions



Source: the authors.

In theory, under full capital mobility, liquidity management is *seamless* and does not rely on central bank intervention in the money market. Changes in autonomous factors, such as the CiC and the government account, reduce or increase bank reserves at the central bank away from equilibrium (R). The excess (shortage) of reserves leads to a change in the domestic short-term money market rate away from the interest rate parity, triggering capital flows that *offset* the change in autonomous factors. As a result, bank reserves remain close to their precautionary demand (R) and the domestic short-term interest rate (money market rate) fluctuates close to the level consistent with the interest rate parity.

A smooth liquidity adjustment as described and discussed above, however, is based on three main assumptions:

- First, banks' liquidity adjustment (management) is made through FX inflows/outflows.

- Second, FX flows should respond efficiently to changes in domestic money market rates. This supposes that there is no delay due to settlement or differences in time zones between the local and anchor country. In addition, even in the absence of capital controls, the interest rate parity may not hold in the short-term in less developed financial markets.

- Third, the domestic interbank market should effectively reallocate reserves. When the domestic interbank market is segmented or shallow, interest rates can be either less

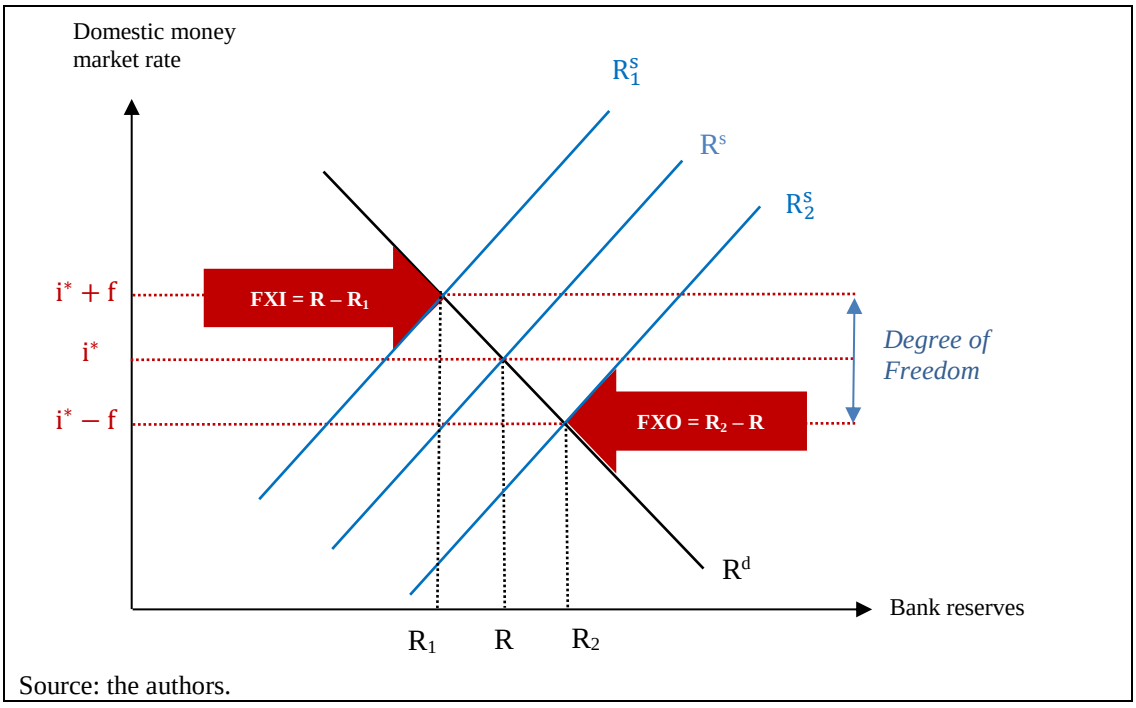
responsive (in the presence of large excess reserves) or overreacting to changes in bank reserves in case of sizeable liquidity shortage.

D. Friction Cost, and Country and Counterparty Risk

In this subsection, we first relax the assumption of the absence of frictions in the FX market.

There is a spread between the buying and selling rates and other costs related to the making of FX transactions, which adds to the cost of financing banks' demand for domestic reserves in the FX market. With the frictions, FX flows respond to domestic rates only after a minimum deviation from the foreign interest rate (+/- f). Domestic short-term rates fluctuate in a corridor defined by the domestic interest rate level that triggers FX flows (Figure 6). In well-developed money markets and in the absence of country and counterparty risk, short-term rates efficiently respond to a small reserve shortage or surplus. In addition, in the absence of limits on foreign and local counterparties, FX flows also efficiently respond to short-term interest rates once they exceed the friction costs. Excess or shortage of reserves compared to bank demand are swiftly and fully *offset* by FX inflows or outflows keeping bank reserves at the central bank close to equilibrium (R).

Figure 6. Short-Term Interest Rate and FX Flows under a Fixed Exchange Rate with Open Capital Account with Frictions



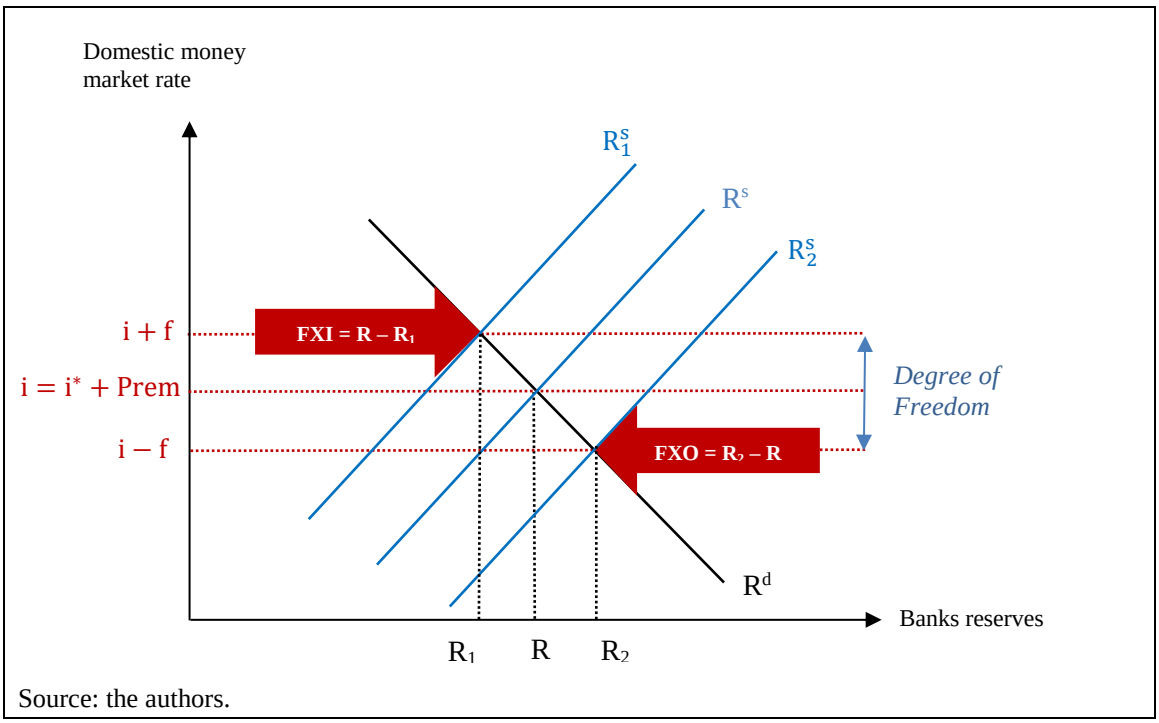
Source: the authors.

We then relax the assumption of no country and counterparty risk.

Local banks are subject to a country-specific risk premium (Prem) that includes counterparty and credit risk. It could be positive or negative and depends on a number of country-specific risk factors, including: the fiscal authority credit rating; the soundness of the local banking

sector; the depth of the local financial markets; the effectiveness of the central bank liquidity management; and the level of FX reserves. The risk premium could vary and increase in times of stress. The introduction of the country risk premium results in a *neutral* interest rate different from the foreign interest rate (Figure 7). The rest of the adjustment mechanism based on capital flows remains the same.

Figure 7. Short-Term Interest Rate and FX Flows under a Fixed Exchange Rate with Open Capital Account with Frictions and Country Risk



Source: the authors.

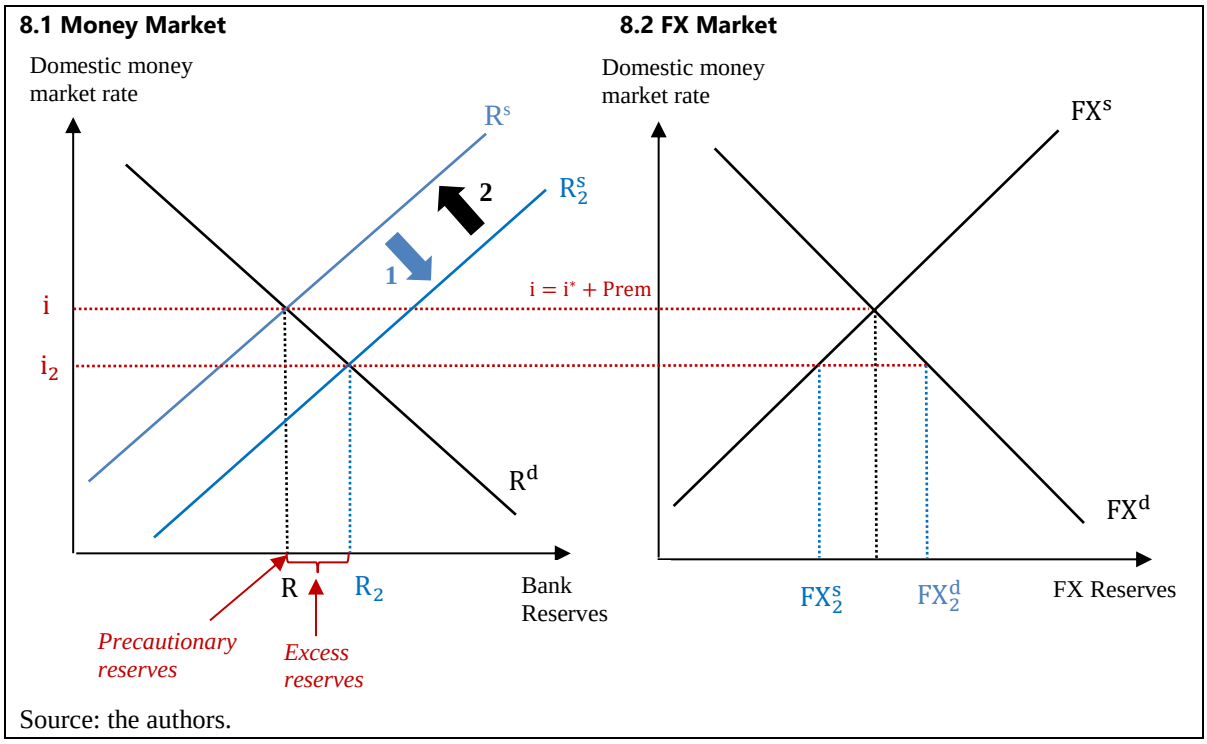
E. Money and Foreign Exchange Market Dynamics

In this subsection, we add the FX market and represent and discuss both money and FX market dynamics. We assume that banks essentially rely on the central bank FX facilities to adjust a surplus or shortage of FX. Figures 8.1 and 8.2 represent the money and FX markets under a fixed exchange rate arrangement. R^d and R^s are the demand and supply of bank reserves in the domestic money market, and i the interest rate that equilibrates the demand and supply (Figure 8.1). Similarly, we refer to FX^d and FX^s as the demand and supply of FX: we assume that the demand for FX increases when the domestic interest rate decreases to below the foreign interest rate (i*) adjusted with the risk premium (Prem), while the supply of FX increases when the domestic interest rate increases.

Figure 8.1 shows the effect of a positive liquidity shock induced by the change in an autonomous factor, for example, an increase of government expenditures that decreases the government account at the central bank. The domestic money market rate decreases from i to i_2, following the positive liquidity shock. At i_2, the domestic interest rate is below the foreign interest rate plus the risk premium. Therefore, the demand for FX at FX_2^d exceeds the supply

of FX at FX_2^s, leaving in the market an excess demand for FX, as shown in Figure 8.2. The central bank, then, satisfies the excess demand for FX by selling FX to banks. This reduces the supply of bank reserves at the central bank to its initial level R^s. The reduction in the supply of bank reserves leads to an increase in the money market rate back to its initial level and a reduction in the excess demand for FX in the FX market. At the end, money and FX markets return to their *neutral* position.

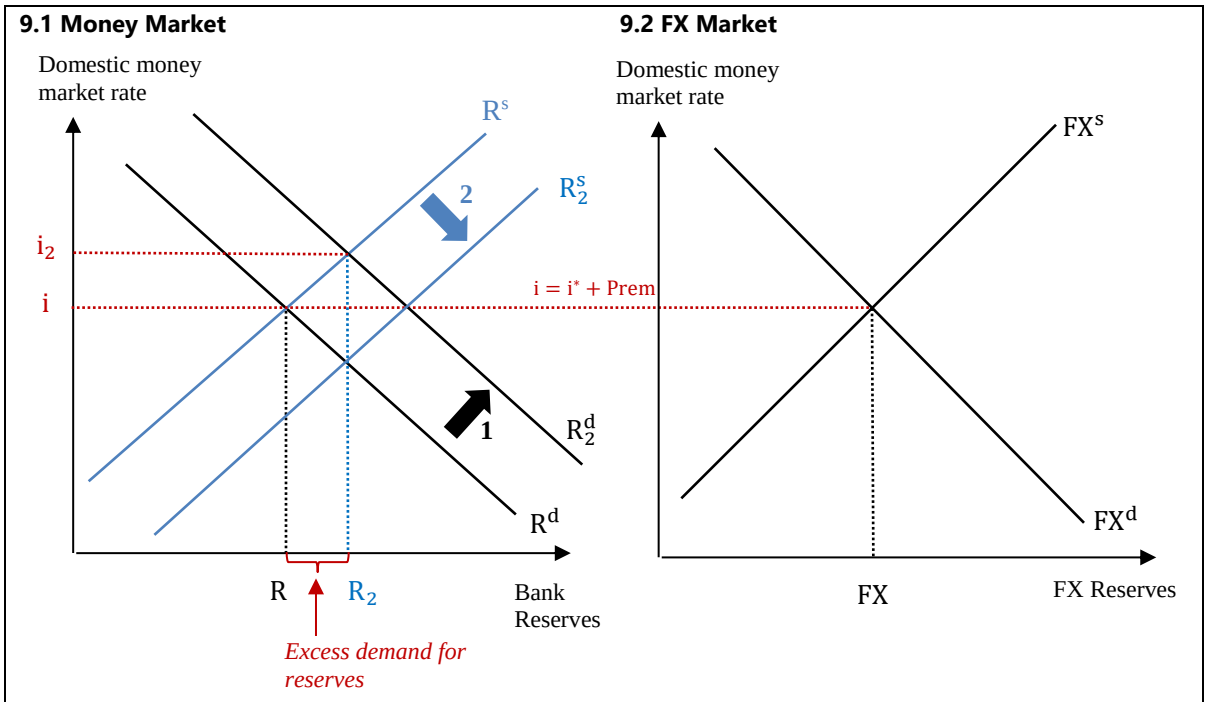
Figure 8. Money and FX Market Adjustments to a Liquidity Shock under a Peg



Source: the authors.

Figures 9.1 and 9.2 show the impact of an increase in bank demand for reserves at the central bank. This scenario assumes that banks increase their precautionary demand for reserves for reasons due to heightened liquidity concerns in the money market. In that case, R^d increases to R_2^d while the supply R^s remains unchanged. At the new interest rate i_2, there is an excess demand for reserves that must be financed (Figure 9.1). The increase in the domestic interest rates above the foreign interest rate encourages banks to convert FX to local currency with the central bank. As a result, the supply of reserves in the money market also increases and short-term rates move back to i.

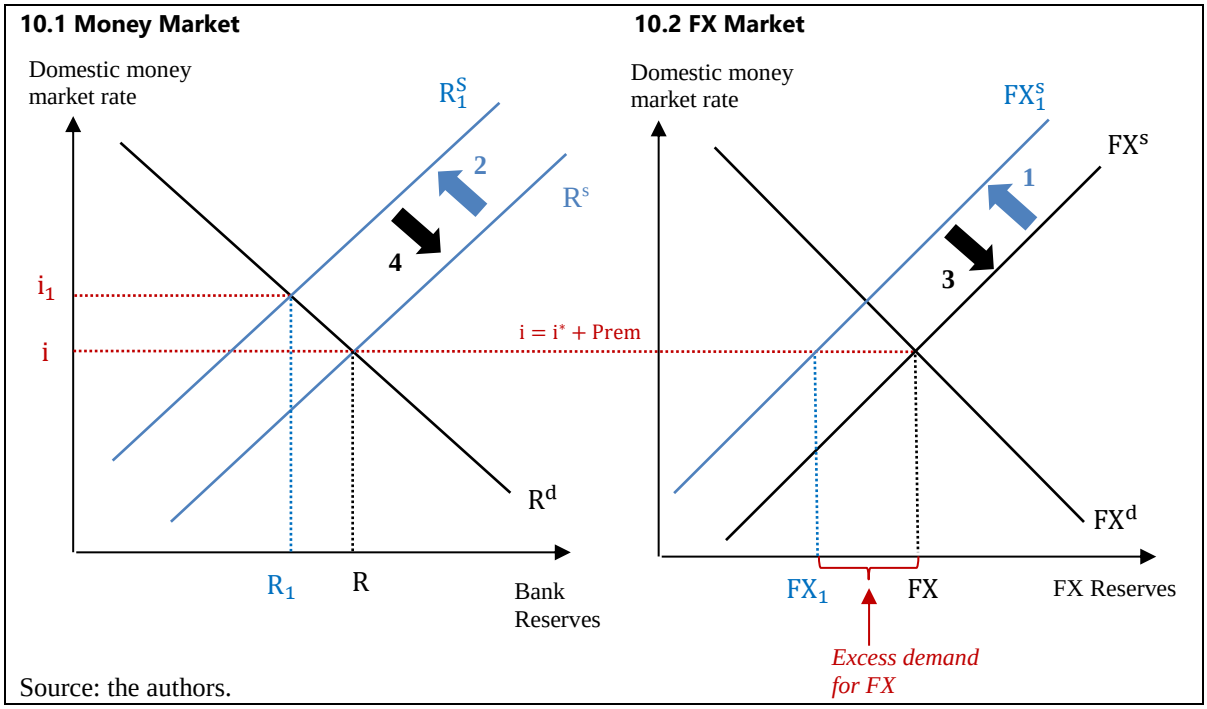
Figure 9. Money and FX Market Adjustments to an Increase in the Precautionary Demand for Reserves



Source: the authors.

Exogenous shocks can also trigger adjustments in the money market. Figures 10.1 and 10.2 show the impact of an adverse ToT shock. The latter reduces the supply of FX in the FX market while the demand remains unchanged. An excess demand for FX appears in the FX market for an unchanged interest rate parity (Figure 10.2). This excess demand is satisfied by FX sales that reduce the supply of bank reserves at the central bank below equilibrium R. As a result, the domestic money market rate increases to above the foreign interest rate plus the risk premium, which, in turn, attracts capital inflows that offset the initial ToT shock. At the end, the domestic money market rate, FX reserves, and bank reserves at the central bank are back to their initial equilibrium position. However, volatility in all these variables may have been large, in the meanwhile depending on the size of the ToT shock.

Figure 10. Money and FX Market Adjustments to a Terms-of-Trade Shock



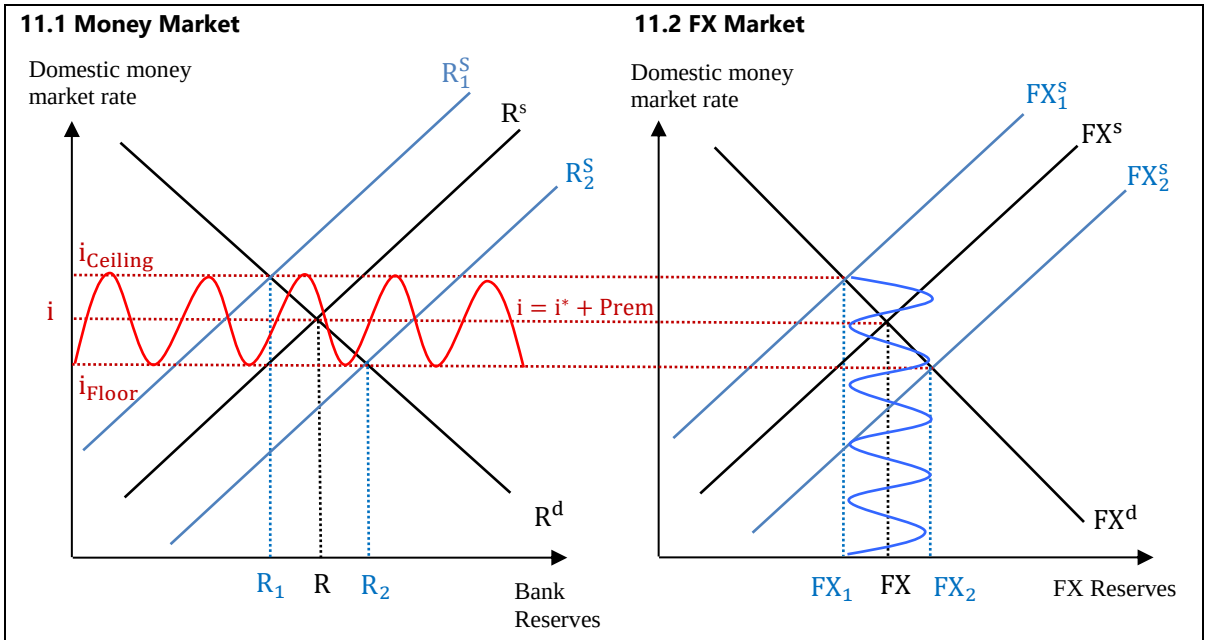
Source: the authors.

Such liquidity dynamics as described in this section lead to unnecessary volatility in domestic money market rates. Each fluctuation in autonomous factors could lead to a change in domestic short-term money market rates, followed by capital flows and/or central bank FX intervention (Figure 11). As a result, the local short-term money market rate is volatile around the level implied by the UIP condition,[5] oscillating around the steady state. Higher volatility in short-term rates increases banks demand for precautionary reserves and reduces their reliance on market funding, impairing, in turn, money market development.

The friction costs and other impairments of the seamless liquidity adjustment can ultimately un-anchor short-term money market rates from the level implied by the UIP condition and jeopardize financial stability. Among autonomous factors, NFA could experience large swings in fixed exchange rate arrangements due to ToT shocks or sudden capital outflows. Higher domestic interest rates may not trigger enough capital flows in the short-term to offset the liquidity shocks induced by autonomous factors. In extreme circumstances of sizeable liquidity shortfalls due to a persistent negative liquidity effect of autonomous factors, domestic interest rates may have to remain high, potentially leading to illiquidity in the banking sector, which could also affect banks' solvency. On the other hand, if capital outflows do not respond to low domestic short-term rates, excess reserves may become persistent, which deters the development of the money market and, in turn, limits the market capacity to absorb idiosyncratic liquidity shocks.

[5] UIP condition states the difference in interest rates between two countries will equal the expected change of the exchange rate.

Figure 11. Money Market Rate Fluctuations in Response to Exogenous Shocks



Source: the authors.

III. From Theory to Practice

A. Liquidity Management Challenges under a Fixed Exchange Rate

Liquidity management under a fixed exchange rate with open capital account can be complicated by its dual objective of steering a short-term money market rate while at the same time defending the peg. Under a fixed exchange rate arrangement where the central bank uses its policy rate to defend the peg (for example, Denmark), both the policy rate and the liquidity management instruments aim at *offsetting* shocks: the policy rate is used to counteract (*offset*) capital flows (exogenous shocks) while the liquidity management instruments *offset* short-term autonomous factors' shocks. The overarching objective of liquidity management frameworks under flexible exchange rate regimes is to steer a short-term money market rate toward a specific level that reflects the monetary policy stance with usually limited financial stability considerations. In contrast, in addition to preserving the fixed exchange rate, liquidity management under a fixed exchange rate with open capital account often has the role of preserving financial stability by offsetting shocks.

A seamless liquidity management purely based on FX flows without central bank intervention, as described in Section II, could lead to significant volatility in short-term money market rates due to the combined effect of autonomous factors shocks and frictions. This justifies the need for central bank intervention to stabilize short-term money market rates. In the absence of an active liquidity management, volatile liquidity conditions could have the following consequences:

- Higher precautionary demand for reserves, leading to an increase in funding costs and lending rates;

- Shallow money markets due to persistent liquidity surpluses that reduce the need for interbank trading;

- Unclear monetary policy signal when the central bank fails to stabilize short-term money market rates close to its policy rate; and eventually

- Large and unexpected changes in short-term money market rates that challenge banks' liquidity and solvency.

Liquidity management under a fixed exchange rate with open capital account presents, however, specific challenges for the central bank:

- Ascertaining friction costs;

- Determining the changes in the risk premium;

- Assessing the precautionary demand for reserves as a function of: the settlement risk and the level of development of the money markets;

- Anticipating changes in the supply of bank reserves (that is, forecasting autonomous factors); and

- Determining the liquidity management instruments needed to *offset* liquidity shocks.

B. Steering Short-Term Interest Rates under a Peg

The level toward which domestic interest rates should be steered can be more difficult to determine in fixed exchange rate arrangements. It typically depends on the level of domestic financial deepening and integration into the global financial markets as well as intensity of capital flows. Central banks of countries with the highest financial integration to the global markets and exposed to larger capital account shocks may need to offset the effect of persistent capital flows using their policy rates. By contrast, countries with less global financial integration and less exposed to capital account shocks may have more autonomy in steering short-term interest rates with deviations from the UIP. Such countries can be tempted to leave unsterilized excess reserves that mechanically decrease money market rates in time of FX reserves accumulation. Nonetheless, sizeable and persistent deviations from the UIP induce imbalances in the money and FX markets and may increase the risk of speculation in times of reversals in liquidity conditions.

While standard liquidity management is dedicated to implement interest rate decisions, the level at which the rates should be steered can be, to different degrees, endogenously determined by the defense of the peg under open capital account. In the conceptual framework presented in this paper, short-term interest rates are in theory adjusted automatically at a level consistent with the fixed exchange rate. But the automatic adjustment

generates more short-term interest rate volatility, higher and unpredictable demand for precautionary reserves, lower money market deepening, potentially higher risk of speculation, and overall less resilience to systemic and idiosyncratic liquidity shocks.

Therefore, two main alternative and practical liquidity management approaches under fixed exchange rate arrangements could be considered:

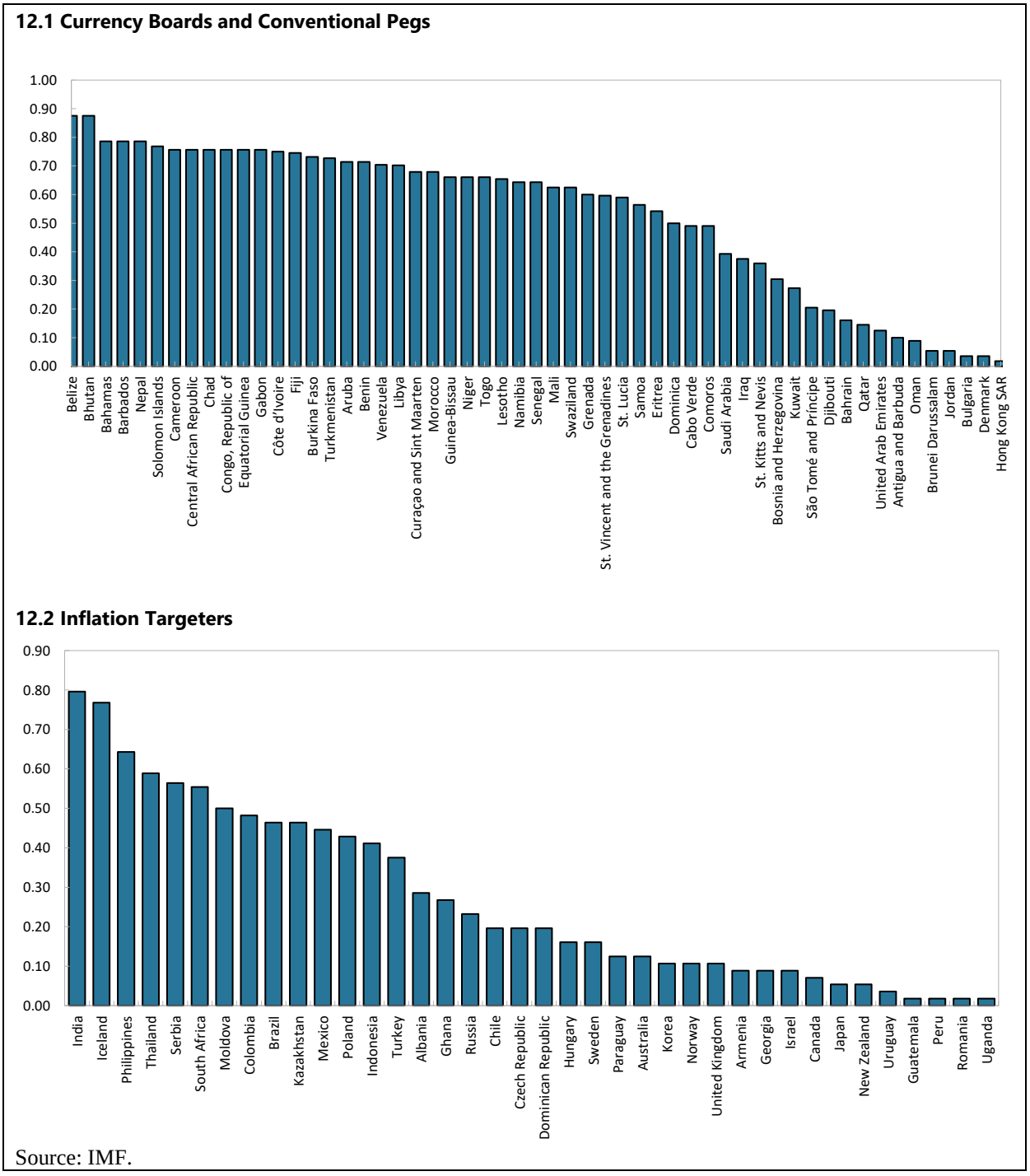
- A first approach where the central bank sets its policy rate in reference to the anchor country policy rate and adjusts the rate as the risk premium changes (UIP condition). The liquidity management framework is, then, akin to the standard one, and the central bank should set up a rule to adjust its policy rate when necessary, sometimes to preserve external stability more than to close an inflation gap and an output gap. In addition, the central bank would have to address the difficulties in calibrating OMOs in a context of more volatile autonomous factor shocks.

- A second one where the central bank leaves to the market to determine the short-term interest rates but uses some liquidity management operations to dampen interest rate volatility. In this approach, the interest rate will be determined similarly to the conceptual framework, but part of the volatility expected from the automatic adjustment is absorbed by liquidity management tools.

The international experience shows a wide range of liquidity management approaches depending on each country's macro-financial conditions and vulnerability to exogenous shocks (current account versus capital account shocks). This spectrum ranges from frameworks with limited liquidity management (Bulgaria), passive liquidity management under structural liquidity surplus (Saudi Arabia), active liquidity management (Denmark), to a standard mid-corridor system (Morocco). Among these economies, Bulgaria, Denmark, and Hong Kong SAR have more open capital account (Figure 12.1). Jordan and Qatar have an open capital account and an interest rate corridor in place. The other countries that operate interest rate corridors, according to the Information System on Instruments of Monetary Policy (ISIMP 2013) and Monetary Operations and Instruments Database (MOID 2018) survey results, have a partially open capital account (Fiji, Morocco, Saudi Arabia, and Swaziland; Appendix III).[6]

[6] For the purpose of this paper, capital account openness is assessed using the Financial Account Restrictiveness Index (FARI). The FARI is prepared by the Monetary and Capital Markets Department of the IMF based on the data reported in the Annual Report on Exchange Arrangement and Exchange Restriction.

Figure 12. Financial Account Restrictiveness Index—Currency Boards, Conventional Pegs, and Inflation Targeters



Source: IMF.

Many central banks with fixed exchange rate arrangements set the level of their policy rate (for example, Denmark, Hong Kong SAR, Morocco, and Saudi Arabia; Appendix I). Where the central bank chooses to set the policy rate, its policy decision can be rule based and consistent with a UIP condition. In a fixed exchange rate arrangement without capital

controls, the ultimate objective of monetary policy is price stability or inflation as the country imports the monetary policy of the anchor country. The exchange rate plays the role of nominal anchor and is strictly fixed to an anchor currency meaning that the central bank fixes the price of the local currency against the anchor foreign currency and does not control the volume of its FX interventions. Under this type of arrangement, the principle of dichotomy between monetary policy decisions and implementation can apply. The setting of the policy rate can be rule based while the liquidity management aims to steer a short-term money market rate (collateralized or uncollateralized). The policy rate can be set close to the anchor country policy rate adjusted by a risk premium:

- Regarding the anchor country policy rate, O/N interest rate swaps for major international currencies provide an indication of the future interest rate path for those currencies.

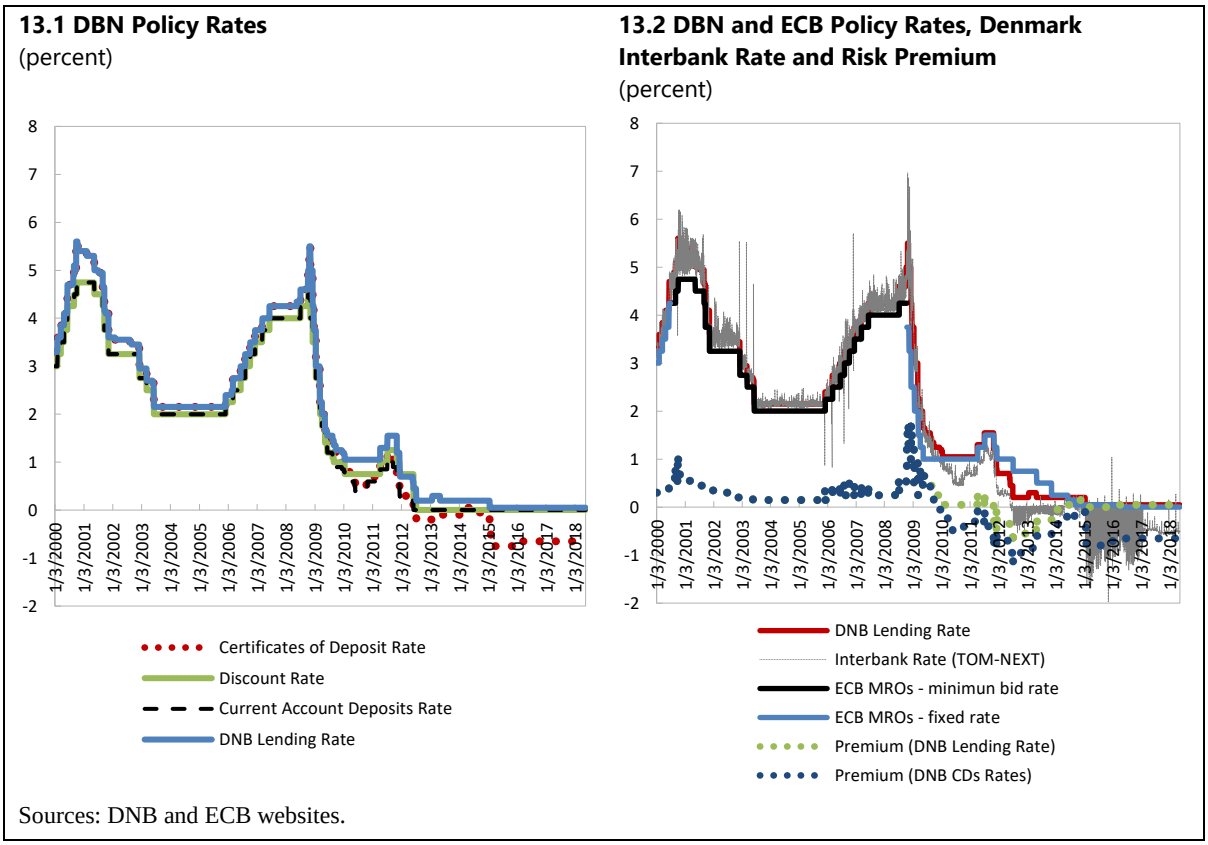
- The risk premium could be assessed based on a set of indicators that reflect the perception of the country risk by its counterparties. Those include the credit default swaps (CDSs) rate, which indicates the pricing of the sovereign risk in the market. CDSs are, however, not available in every market. In addition, CDSs only provide a basis to which an assessment of the overall local banking sector credit risk should be added, as well as the liquidity premium that depends on the level of development of local markets.

The Danmarks Nationalbank (DNB), for example, sets the monetary policy interest rates under a pegged exchange rate to the euro. DNB monetary policy interest rates are: the lending rate; the certificates of deposit (CDs) rate; the discount rate; and the current-account rate. DNB policy rates are geared to the management of the exchange rate and are not used for the management of the business cycle. When there are no pressures on the FX market, the DNB usually changes its interest rates in step with the European Central Bank (ECB) policy rate (Figure 13.2). In times of upward or downward pressures on the exchange rate, the DNB changes its interest rates in order to stabilize the krone. In the short term, the DNB can also influence the krone exchange rate by intervening in the FX market.

The difference between the DNB and ECB's policy rates depends on the relative market perception of the country risk between the anchored and the anchor country. The anchor country risk is usually lower, as the anchor is usually a larger economy. However, in the specific case of Denmark and the euro area, the spread turned negative due to concerns regarding the euro area future during the crisis as the DNB tried to discourage capital inflows. According to the DNB, in a situation of negative interest rate on CDs, it is crucial that the monetary policy counterparties' holdings of CDs are sufficient to ensure the transmission from CDs' interest rates to money-market rates.[7]

[7] DNB website.

Figure 13. DNB and ECB Policy Rates



Sources: DNB and ECB websites.

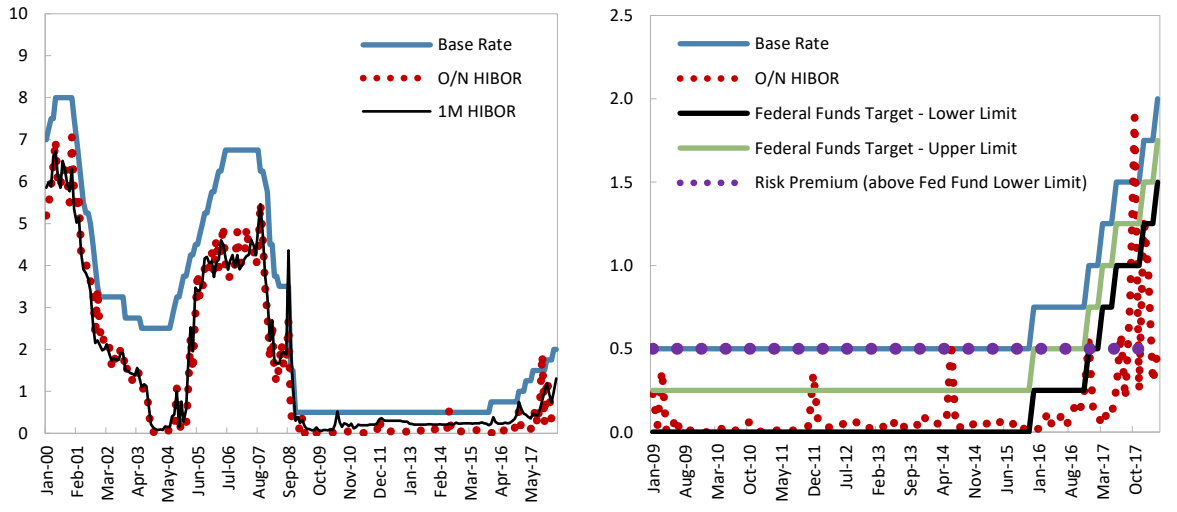
The Hong Kong Monetary Authority (HKMA) sets the level of the base rate every day. The base rate was introduced in September 1998 to address the tradeoff between interest rates' adequate responsiveness to capital flows and dampening excessive and destabilizing interest rate volatility.[8] The base rate is the interest rate used to compute the discount window rate. It is currently set at 50 basis points above the prevailing US Fed Fund target rate or the average of the five-day moving averages of the O/N and one-month Hong Kong InterBank Offered Rates (HIBORs), whichever is the higher (Figure 14.1). The HKMA announces the base rate every day before the interbank market opens in Hong Kong SAR.[9]

Since 2009, the risk premium of the base rate (above the lower limit of the Fed Fund target) remained stable at 50 basis points. The base rate has followed the same tightening cycle as the Fed Fund target rates since December 2015. The O/N HIBOR has displayed significant volatility since then, with the increased outflow pressure (Figure 14.2). To maintain the peg, the HKMA purchased HKD and sold USD upon requests from banks at 7.85 Hong Kong dollars per US dollar, resulting in reduced aggregate balance in the banking system and higher interbank interest rates.

[8] http://www.hkma.gov.hk/eng/key-information/press-releases/1998/981126.shtml.

[9] http://www.hkma.gov.hk/gdbook/eng/b/base_rate.shtml.

Figure 14. HKMA Base Rate and Fed Fund Target Rates



Sources: HKMA and Federal Reserve Bank of St. Louis websites.

One of the Saudi Arabian Monetary Authority (SAMA) key monetary policy rate, that is, the O/N reverse repo rate, also closely tracks the Fed Fund target (lower bound).[10] Monetary policy is decided by SAMA's Monetary Policy Committee (MPC) that meets at a minimum eight times a year; ad hoc meetings may be called to respond to any development. The Saudi Arabian banking system is in structural liquidity surplus primarily due to oil-related flows and the fixed exchange rate. SAMA issues SAMA bills[11] to sterilize excess liquidity from the system. SAMA liquidity management is essentially passive and geared toward the sterilization of excess liquidity. When liquidity temporarily tightened in 2016 due to the fall in oil prices, SAMA eased the loan-to-deposit ratio, reduced the weekly issuance of SAMA bills from 9 billion SAR to 3 billion SAR, offered term repurchase facilities,[12] and provided liquidity to banks through the placement of deposits.

SAMA has a variable width interest rate corridor; however, since 2009, the system de facto operated as a floor due to the liquidity surpluses generated by oil revenues. Since mid-2009, the floor, that is, the reverse repo rate, remained equal to the Fed Funds Target (lower bound). The ceiling, that is, the O/N repo rate, has stayed at the same level close to 2 percent

[10] SAMA considers both the Repo and reverse Repo rates as key policy rates. The Saudi Arabia riyal has been pegged at 3.75 to the USD since 1986.

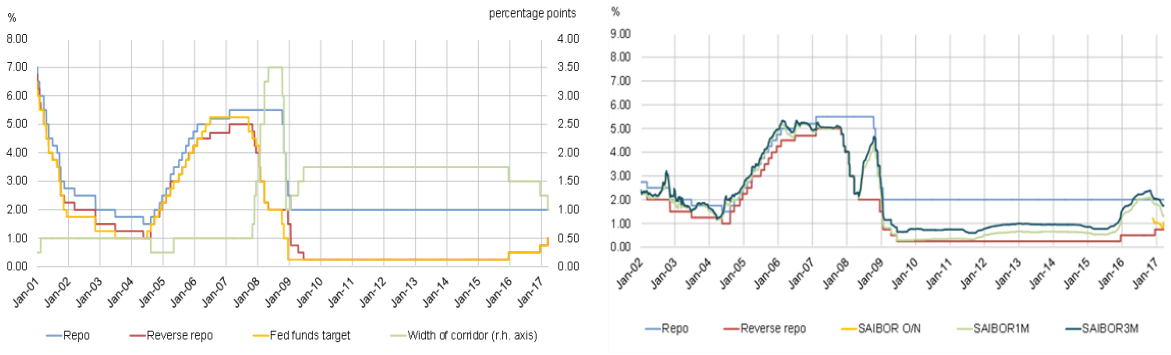
[11] With one-, four-, 13-, 26-, and 52-week maturities.

[12] In response to the liquidity squeeze in October 2016, SAMA introduced "on a temporary basis" and in an effort to dampen volatility in three-month SAIBOR, longer term lending facilities with maturities of seven days, 28 days, and three months.

since the beginning of 2009 until March 2018 when it was gradually increased to 3 percent currently. Accordingly, the corridor narrowed with the Fed's interest rates hikes since end-2015.

Figure 15. SAMA Policy Rates and Fed Fund Target Rate

15.1 SAMA Policy Rates and Fed Fund Target Rate **15.2 SAMA Policy Rates and SAIBOR**



Source: SAMA.

An interesting common feature of the DNB and the HKMA is the use of a discount window rather than an O/N standing credit facility that imposes a firm ceiling on money market rates.[13] In general, a discount window can be different than an O/N standing credit facility. Depending on how it is operated, a discount window can be at longer maturities than O/N; it allows more flexibility in its use by the central bank than an O/N standing facility (SF). By contrast, an O/N SF is always at bank's initiative, with a fixed interest rate and standard maturity. When implementing such a facility, the central bank stands ready to supply whatever amount of O/N reserve balances are demanded at a fixed interest rate: the ceiling of the corridor.

Indeed, central banks operating fixed exchange rate arrangements under a high degree of capital mobility can find it difficult to maintain corridors in times of rapidly decreasing NFA and high devaluation expectations or pressures on the exchange rate. Reconciling the two objectives of maintaining an O/N standing credit facility and fighting speculative attacks may not be feasible. For example, the DNB decided to abolish the use of such a facility because it has experienced several bouts of speculation. In addition, the DNB sets a limit on current-account deposits, which is a ceiling on the monetary policy counterparties' total current-account deposits. The purpose of this limit is to prevent the buildup of large deposits that may be unduly used for speculation if the krone is under pressure. If the overall limit for all counterparties is exceeded, current-account deposits exceeding the individual limits are converted into CDs.

[13] Under normal circumstances, the use of the discount window of the HKMA is at a bank's initiative based on the prices and eligible collateral set by the HKMA, rather than HKMA's discretion.

On the other hand, both interbank interest rates in Hong Kong SAR and Saudi Arabia stayed close to the zero lower bound following the cut in the Fed Fund target rate to 0–0.25 percent in 2009. Yet leaving sizeable excess liquidity in the system makes it more prone to volatility in a time of reversal in liquidity conditions; both the HIBOR (Figure 14) and Saudi Arabia InterBank Offered Rate (SAIBOR) (Figure 15) displayed increasing volatility in the subsequent period (2016–18).

A fixed-width mid-corridor system appears easier to operate when the economy is not subject to large and disturbing capital inflows/outflows and when the local currency is not under unsustainable pressure. Countries with fixed exchange rate arrangements can—under certain preconditions—implement a mid-corridor system that stabilizes short-term fluctuations of money market rates. There are, however, strong preconditions to the successful implementation of corridor under fixed exchange rate arrangements: adequate liquidity forecasting framework; absence of speculation or unsustainable pressures on the peg; existence of an active interbank market; clear separation between the monetary policy operational framework and the lender of last resort framework; and relatively developed fixed income markets that provide the sufficient eligible collateral. In the following subsections, we discuss the importance of OMOs and SFs combined to reserve requirements and averaging for fixed exchange rate arrangements.

C. **Open Market Operations and Autonomous Factor Forecasts**

Several central banks operating under fixed exchange rate arrangements have introduced OMOs to offset short-term liquidity shocks and stabilize short-term money market rates. Jordan, Morocco, Nepal, and Oman have weekly OMOs conducted as repo operations, while others offer term SFs to inject and/or withdraw liquidity in the system (Appendix II). Weekly OMOs support money market development, as a too high frequency (daily) will not provide incentive for market participants to trade, while a too low frequency increases the likelihood of money market rates deviation from the policy rate. A full-allotment type of auction under a fixed exchange rate arrangement may defeat the objective of offsetting liquidity shocks while at the same time increasing the risk of over-injection.

When the banking system is in structural liquidity surplus, a liquidity absorbing OMO is usually conducted by the central bank. The operation can take the form of an auction-based issuance of short-term central bank securities (or deposit auction). The central bank is expected to offset the short-term liquidity effect of autonomous factors on bank reserves by decreasing or increasing the outstanding amount of securities or deposits offered. According to the ISIMP (2013) and MOID (2018) survey results, Bulgaria and Kuwait had a one-week auction-based deposit as part of their liquidity management framework while Nepal, Qatar, and Swaziland relied on bilateral deposits. Several central banks with fixed exchange rate arrangements issue their own securities: Bhutan, Denmark, Fiji, Hong Kong SAR, Jordan, Kuwait, Solomon Islands, Samoa, and UAE. Few issue one-week tenor central bank securities (Jordan, UAE) while a number issue on longer maturities, up to five years (Appendix II).

The issuance of longer-term central bank securities may be considered when the government securities market is shallow. Some central banks issue, via competitive auction, longer-term

securities (for example, 90 days) with market-determined interest rates to absorb liquidity surpluses. In practice, central bank securities replace low yield excess reserves—that are available for FX purchases—with higher yields, risk-free securities that lock up liquidity for a minimum period of time. Such an approach may help keep excess reserves low and provide a larger pool of High Quality Liquid Assets (HQLA), especially for repos. The central bank itself can participate in the market of its own securities.

OMOs can be more difficult to calibrate under a fixed exchange rate without capital controls due to FX interventions. Indeed, under a peg, the central bank fixes the price of the local currency against the anchor foreign currency and does not control the volume of its FX interventions. Forecast errors can be larger, as the quality of the forecast depends on the capacity of the central bank to predict the volume of its FX interventions in the short run. While capital flows and ToT shocks can be unpredictable over the medium term, the central bank can produce short-term (up to five days) forecasts of FX interventions using the standard t+2 settlement delay and aggregation of its counterparties' individual forecasts. The reliable forecast horizon is limited (up to five days). Where the settlement delay of FX operations is t+0, FX interventions become unpredictable under a peg. Domestic autonomous factors, mainly the CiC and the government account, could be forecasted as in other exchange rate arrangements, with forecast errors depending on the central bank autonomous factors' forecast quality and efficiency of the government cash management.

When expected to be sizeable and persistent and not properly forecasted and offset by the central bank, capital outflows and negative ToT shocks exacerbate market expectations and the risk of speculation. In some cases, the higher likelihood of liquidity shocks under a fixed exchange rate arrangement and the limited pool of HQLA in smaller markets contribute to boost the demand for precautionary reserves, which is thus less stable. Limiting the risk of speculation often requires limiting banks' excess reserves, which could be used to finance large FX purchases in an environment where the demand for precautionary reserves is potentially higher.

Liquidity forecasting practices vary across central banks adopting fixed exchange rates, as is the case for those operating market-determined exchange rates. Those with more sophisticated liquidity management frameworks or operating mid-corridor systems have full-fledged forecasting frameworks. Others are not conducting any forecasting, reflecting the absence of active liquidity management. An incomplete liquidity forecasting framework can also indicate the difficulties of forecasting government revenues and expenditures in the absence of a single treasury account, and good coordination between the monetary and fiscal authorities rather than the difficulty of forecasting FX flows. It can also reflect the incapacity of the central bank to centralize and produce the daily data necessary for the liquidity forecasting rather than the constraints imposed by the peg.

D. The Role of the Reserve Requirements Mechanism

The central bank's first best option to address larger and more frequent forecast errors is to introduce reserve requirements with averaging. Averaged reserve requirements relax the need for perfectly accurate liquidity forecasts because they absorb unexpected liquidity shocks and reduce the demand for precautionary reserves when full averaging is allowed. To be

effective, the reserve requirement should provide enough averaging room on a relatively long reserve maintenance period. The reserve requirement can ensure a minimum demand for central bank funding in the domestic market, when the reserve requirement ratio can be set sufficiently high to generate a structural liquidity deficit.

The reserve requirement ratio should be kept at a level that maintains a sufficient (but not too large) demand for OMOs. A low demand for OMO and, accordingly, a low stock of central bank's securities (or refinancing) reduces the traction that OMOs have on short-term money market rates. There is, thus, a tradeoff between the reserve requirement function as a buffer and the optimal stock of OMOs.

According to the ISIMP (2013) and MOID (2018) survey results, most central banks operating under currency boards or conventional pegs had reserve requirements with averaging in place, usually with an approximately one-month or more reserve maintenance period. Full averaging is allowed when reserve averaging is in place. Eight countries/monetary unions had less than a four-week reserve averaging period: ECCU, Lesotho, Nepal, Swaziland, UAE, and Venezuela (one week), Bosnia Herzegovina (10 days), and Jordan (two weeks). Denmark, Djibouti, Hong Kong SAR, and Kuwait had no reserve requirements in place. However, only a few countries provided remuneration for the required reserves (Appendix IV).

Some central banks operating under fixed exchange rate arrangements prefer to sterilize liquidity surpluses, mainly using the issuance of central bank instruments (securities or deposits) rather than using the reserve requirements. However, the issuance of longer term instruments cannot substitute the buffering role of reserve averaging.[14]

The required reserves should be remunerated close to their opportunity cost when the reserve requirement ratio is relatively low and the central bank objective is not to curb excessive credit growth. The objective of the remuneration is to prevent a change in the level of the reserves required for liquidity management from having an impact on counterparties' funding cost, which may not be consistent with the policy stance transmitted via the policy rate.

The reserve requirement ratio helps sterilize large persistent liquidity shocks induced by persistent exogenous shocks; reserve averaging, on the other hand, absorbs unexpected short-term autonomous factor shocks. Structural excess liquidity needs to be sterilized through structural monetary policy instruments rather than short-term operations to leave room for interbank market development while at the same time containing inflationary pressures and excessive credit growth. The reserve requirement ratio can be increased to mop up structural liquidity surpluses created by a persistent FX reserve accumulation and decreased in the face of persistent capital outflows or adverse current account shocks. On the other hand, reserve averaging allows banks to undershoot or overshoot their requirement on any day, incentivizing them to trade in the interbank market. Averaging is particularly useful when it is difficult for the central bank to forecast accurately all flows across its balance sheet, since

[14] For further details on issuance of central bank securities, see Gray and Pongsaparn (2015).

averaging creates an intertemporal liquidity buffer to offset errors in the central bank's forecast.

E. The Standing Facilities

Liquidity management SFs include the O/N credit and deposit facilities. Regardless of the exchange rate arrangement, the spread should exceed the cost of transactions in the domestic money market to encourage interbank trading and reduce the recourse to the SFs.

In some fixed exchange rate arrangements, the introduction of SFs is complicated and can be challenging for the following reasons:

- A deposit rate set too high would increase the reserves deposited at the facility, discouraging capital outflows. It would also increase the cost of the central bank liquidity management.

- Counterparties can use the standing credit facility to purchase FX against domestic currency collateral in times of pressures on the NFA and the peg, and increase the likelihood of the devaluation by doing so.

As a result, the spread between the liquidity management facilities, if they are introduced, are usually rather large.

According to the ISIMP (2013) and MOID (2018) survey results, few central banks operating under a currency board or conventional pegs had both an O/N standing credit and deposit facility in place: Fiji, Jordan, Morocco, Qatar, Saudi Arabia, and Swaziland (Appendix III).

F. Refinancing and Collateral Framework

Local counterparties could experience a refinancing need at the aggregated level in fixed exchange rate arrangements without capital controls in specific circumstances for two reasons:

- A large and persistent change in autonomous factors, such as a ToT shock (for example, an oil price slump for oil-exporting countries), leads to a persistent drain in reserves.

- A large increase in the demand for precautionary reserves due to an increase in counterparties and credit risk perception in the domestic market. Some counterparties can refuse to lend in the domestic interbank market, accumulating excess reserves at the central bank or investing them in FX despite the local currency premium. At the same time, others may lose access to domestic or international money markets, even if they pay the premium or offer collateral.

Persistent and negative liquidity shocks arising from autonomous factors are first addressed by the buffers accumulated at the central bank *ex ante*, such as the stock of central banks' securities and the reserve requirements. Once these buffers are depleted, central bank refinancing emerges as the ultimate liquidity buffer against autonomous factor shocks.

The demand for refinancing emerging from idiosyncratic liquidity shocks is more frequent in segmented and less developed interbank markets. Solvent counterparties may not be able to finance a reserve shortage in the interbank market if the market lacks depth or risk perception prevails. If the counterparty has eligible collateral that could not be sold in the market because of the lack of secondary market, the central bank could provide the refinancing at its monetary operations (the refinancing OMO or credit facility). If the counterparty does not have eligible collateral for standard liquidity management operations, the refinancing need would have to be addressed on an emergency liquidity assistance basis.

A relatively large stock of government securities would provide the preferred collateral for monetary policy operations. However, central banks may have to develop a broader collateral framework, including credit claims with the appropriate risk control measures and haircuts, to equalize the residual risk across different classes of collateral. The broader collateral framework would also serve for emergency liquidity assistance.

IV. Offsetting FX Flows and Offset Coefficients

Several empirical papers studied the degree of monetary policy autonomy under a fixed exchange rate arrangement. The underlying assumption is that when capital flows are very responsive to domestic interest rates, the effect of a monetary tightening can be *offset* by capital inflows, leaving little room for an autonomous monetary policy. This line of work was initiated by Manfred Willms (1971) in a paper on whether Germany could tighten monetary policy without risking capital inflows that would offset the monetary policy tightening. Then, several empirical studies, based on a theoretical money market equilibrium model (money demand-money supply equilibrium) aimed at estimating "offset coefficients" (Kouri 1975; Obstfeld 1980; Roubni 1989; Ljuba, Martinis, and Mrkalj 2010; and Kamas 1986). Offset coefficients usually capture the degree of which a monetary tightening spurs additional capital inflows.

Compared to the existing literature, this paper takes a different and more operational approach while building on the same theoretical background. Rather than assessing the degree of monetary policy freedom in the face of offsetting capital inflows, we explore the capacity of the central bank to offset (or sterilize) FX flows (current account or capital account flows) using a combination of policy and operational tools: policy rate, reserve requirements, and OMOs. For this, we do not start from the equality between money demand and money supply as in Kouri (1975); we rather derive the equations we would like to estimate directly from the central bank balance sheet (equality between central bank assets and liabilities). In addition, rather than decomposing the NFA change in its current account and capital account components as in Kouri (1975), we disaggregate the other components of the central bank balance sheet (net domestic assets and monetary base) as follows:

$$NFA = R + LA - LP + CiC + GOV + OIN \quad (1)$$

R being bank reserves at the central bank, CiC the currency in circulation, GOV the government account at the central bank, LA the central bank liquidity absorption operations, LP its liquidity-providing operations, and OIN the other items of the central bank balance sheet.

We emphasize in this paper that the central bank may have some control over bank reserves only and not the monetary base, since CiC is an autonomous factor. Though there are interesting similarities between the quantity theory of money and the liquidity forecasting practice of central banks, there is a distinct and crucial difference between these two frameworks: under the quantity theory of money and the money multiplier belief, the central bank can control the money supply through its control over reserve money; under the liquidity forecasting framework, CiC, though a component of reserve money, is usually outside the control of the central bank.

To assess the extent to which monetary policy implementation *offsets* the effect of FX flows on banking system liquidity, which we define as bank reserves (R), we estimate the three following equations:

$$\Delta NFA_{i,t} = \alpha_1 \Delta i_{i,t} + \alpha_2 \Delta R_{i,t} + \alpha_3 \Delta LP_{i,t} + \alpha_4 \Delta LA_{i,t} + \alpha_5 \Delta CiC_{i,t} + \alpha_6 \Delta GOV_{i,t} + \varepsilon_t \quad (2)$$

$$\Delta LP_{i,t} = \alpha_1 \Delta i_{i,t} + \alpha_2 \Delta R_{i,t} + \alpha_3 \Delta NFA_{i,t} + \alpha_4 \Delta LA_{i,t} + \alpha_5 \Delta CiC_{i,t} + \alpha_6 \Delta GOV_{i,t} + \varepsilon_t \quad (3)$$

$$\Delta LA_{i,t} = \alpha_1 \Delta i_{i,t} + \alpha_2 \Delta R_{i,t} + \alpha_3 \Delta LP_{i,t} + \alpha_4 \Delta NFA_{i,t} + \alpha_5 \Delta CiC_{i,t} + \alpha_6 \Delta GOV_{i,t} + \varepsilon_t \quad (4)$$

Where:

$i_{i,t}$ is the country i policy rate at time t
$R_{i,t}$ are bank reserves of country i at time t
$LP_{i,t}$ is the outstanding volume of the central bank liquidity-providing operations of country i at time t
$LA_{i,t}$ is the outstanding volume of the central bank liquidity absorption operations of country i at time t
$CiC_{i,t}$ is the CiC in the liability side of the central bank balance sheet of country i at time t
$GOV_{i,t}$ is the government deposit at the central bank of country i at time t
$NFA_{i,t}$ are the NFA of the central bank of country i at time t
ε_t is the error term

We estimate the four equations for Denmark and Hong Kong SAR. Following the estimations, we analyze some statistical tests applied to the estimated coefficients.

For equation (2) we test the following hypothesis:

Test 1: the central bank does not offset the changes of the NFA using its policy rate (H0). Under H0, $\alpha_1 = 0$.

The objective of test 1 is to assess whether the central bank uses its policy rate ($i_{i,t}$) to react to FX flows ($\Delta NFA_{i,t}$) and stabilize the NFA. The result of this statistical test is directly provided with the regression outputs in standard statistical software tools; the t-statistic and the associated p-value are used to reject or accept H0.

For equation (3) we test the following hypothesis:

Test 2: the central bank does not offset (that is, sterilize) the changes of the NFA adjusting the volume of its liquidity-providing OMO (H0). Under H0, $\alpha_3 = 0$.

The objective of test 2 is to assess whether the central bank adjusts the volume of its liquidity-providing operations ($LP_{i,t}$) to sterilize the effect of the NFA on bank reserves. The results of the statistical test (as well as the following tests) are also directly provided with the regression outputs.

For equation (4), we test the following hypothesis:

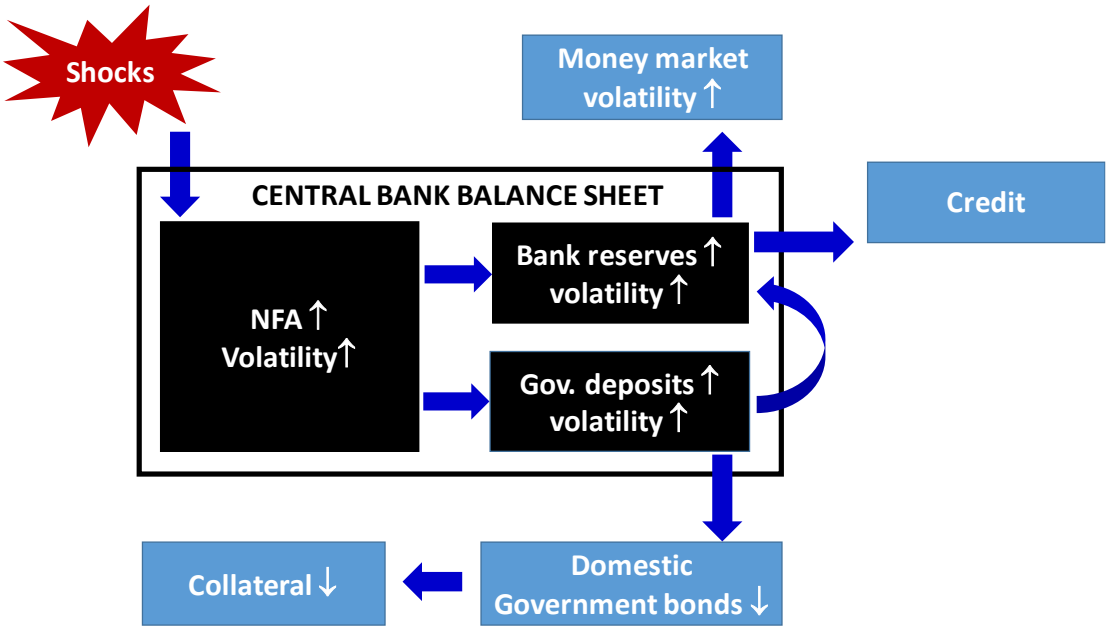
Test 3: the central bank does not offset (that is, sterilize) the changes of the NFA adjusting the volume of its liquidity absorption OMO (H0). Under H0, $\alpha_4 = 0$.

The objective of test 3 is to assess whether the central bank adjusts the volume of its liquidity absorption operations ($LA_{i,t}$) to sterilize the effect of the NFA on bank reserves.

In a fixed exchange rate arrangement, the exchange rate is not allowed to move to correct external disequilibria; consequently, the NFA are expected to be more volatile and so bank reserves in the absence of central bank liquidity management operations. When exogenous shocks take the form of commodity exports (for example, oil exports), the public sector can have a monopoly over the commodity revenues that it uses to finance its public deficit. In such cases, not only the NFA and bank reserves increase and become more volatile in the absence of central bank intervention in the money market, but the domestic government bond market can also be shallow, reducing the available collateral for central bank liquidity management operations (Figure 16).

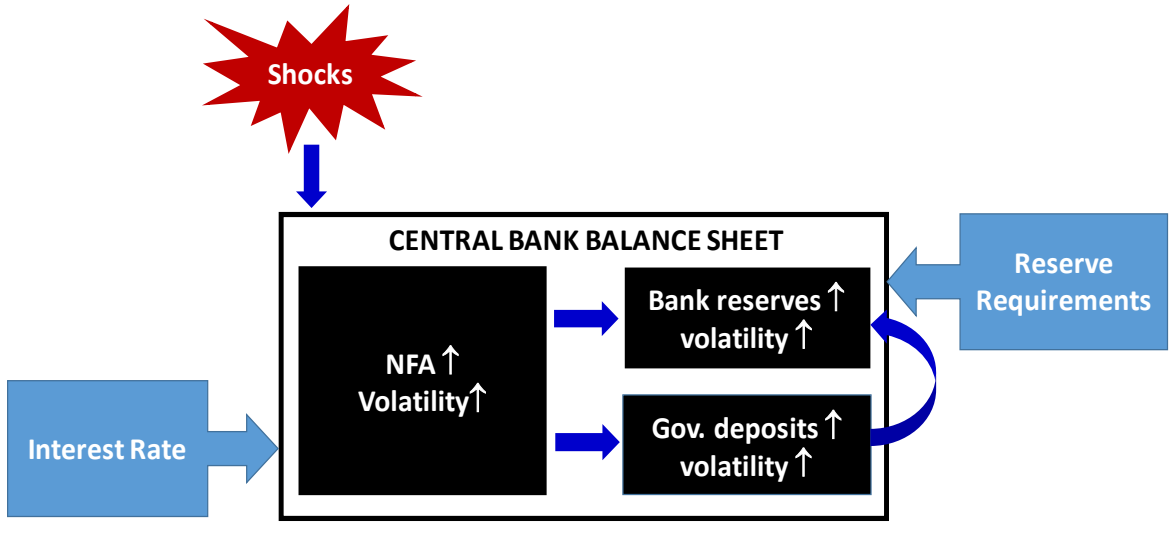
To offset NFA fluctuations and their consequences on bank reserves and the money markets, central banks can use two main structural instruments: the policy rate and the reserve requirements. The policy rate can be particularly useful when the economy is exposed to capital account shocks that are responsive to the central bank policy rate: in such a case, the policy rate can be used to stabilize both the NFA and bank reserves. When capital flows are not responsive to the central bank policy rate and the country *de facto* accumulates large FX reserves that increase liquidity surpluses, the reserve requirements need to be used as a structural instrument (Figure 17).

Figure 16. Exogenous Shocks and Liquidity Dynamics—No Central Bank Liquidity Management Operations



Source: the authors.

Figure 17. Offsetting Exogenous Shocks—Structural Offset Instruments



Source: the authors.

In the following, we estimate individual countries' regressions (equations [2], [3], and [4]) using quarterly time series. Whenever needed, we include explanatory variables' lags. Estimations and results are presented in the following subsections.

A. Denmark

Denmark maintains a fixed exchange rate vis-à-vis the euro area and participates in the European Exchange Rate Mechanism at a central rate of 746.038 krone per 100 euro with a fluctuation band of +/- 2.25 percent. DNB policy rates are: the lending rate, the CDs rate, the discount rate, and the current-account rate (Figure 13). Each monetary policy counterparty holds a current account at the DNB, into which it can make O/N deposits, which accrue interest at the current-account rate.

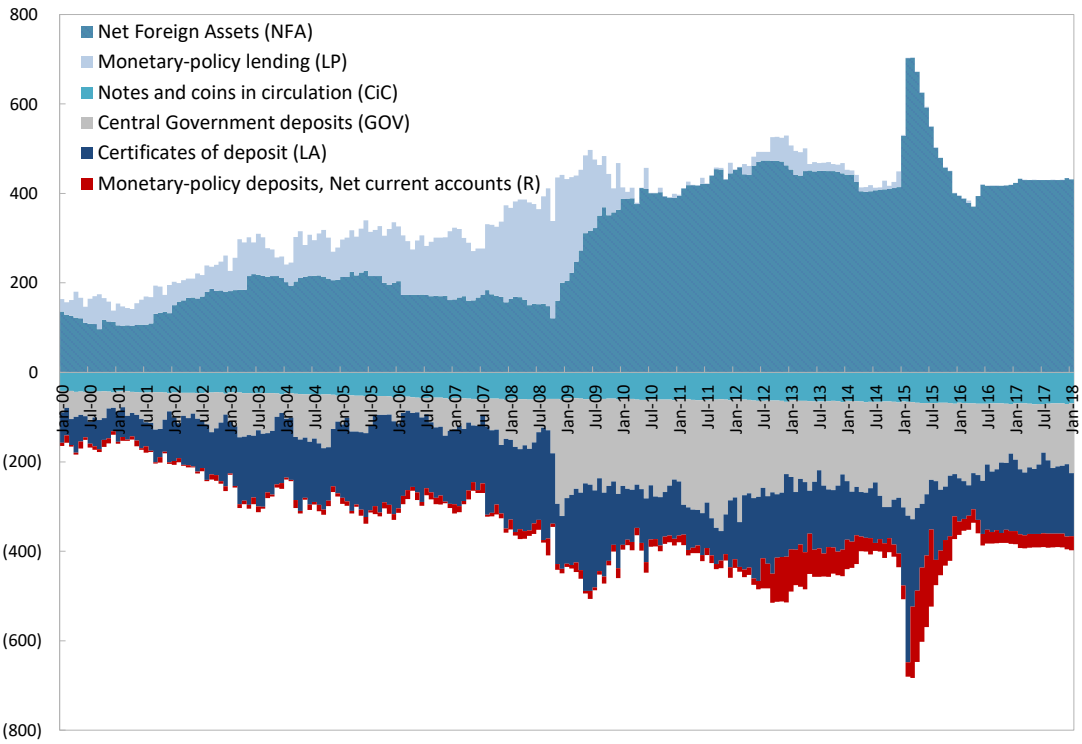
On the last banking day of each week, the DNB conducts OMOs: monetary policy counterparties can borrow from the central bank against collateral and make deposits by purchasing CDs issued by the DNB, usually with a seven-day maturity. The loans and deposits accrue interest at the lending rate and the CDs rate, respectively. The DNB fixes the rates of its OMOs, and counterparties are free to determine the volume of monetary-policy loans and deposits. On all banking days other than the last of the week, the DNB offers purchase and sale of CDs. In connection with the buybacks of CDs, the DNB adds a premium to the rate of interest on CDs when calculating the price for the certificates. The premium gives the counterparties an incentive to exchange liquidity in the money market instead of selling the CDs to the central bank.

In order to support the fixed exchange rate policy, the DNB can also conduct liquidity adjusting operations in the money market when needed. The operations can be conducted either as deposits at the DNB, lending against pledging of assets, or FX swaps. The DNB allocates or absorbs the krone liquidity by auction or conducts bilateral transactions. The operations can be conducted with all monetary-policy counterparties or with a smaller group of counterparties[15].

Since 2010, the DNB balance sheet size appears to have stabilized (except the temporary spike of early 2015), and its balance sheet (Figure 18) does not display such expansion as observed in the HKMA Exchange Fund balance sheet in the post-2008 period (Figure 3 above).

[15] http://www.nationalbanken.dk/en/monetarypolicy/instruments/Pages/default.aspx.

Figure 18. DNB Simplified Balance Sheet



Source: DNB website.

We estimate equation (2) to test whether the DNB may use its policy rate to stabilize the size of its balance sheet, that is, to counteract capital flows and offset their liquidity effect. First, we use the DNB lending rate as an explanatory variable and found that it is not statistically significant. Second, we use the interest rate differential between Denmark and the euro area, which is the DNB lending rate minus the ECB policy rate (i-i*) as independent variable; this interest rate differential is also the risk premium, since the exchange rate is fixed (i=i*+Prem). The ordinary least square regression results are presented in Appendix VI, Table 1. All the variables used in the regression are in first difference (except the interest differential already expressed as a difference) and stationary according to Augmented Dickey-Fuller tests. The estimation period for Denmark is 2000Q4–2017Q4.

We found that a 1 percentage point increase in the interest rate differential at t-3 (three quarters ahead) increases the NFA change by DKK 2.7 billion; the regression coefficient is statistically significant at a confidence level of 90 percent (p-value < 0.1), and we reject the null hypothesis of a zero coefficient under test 1 (Appendix VI, Table 1). This suggests that the interest rate differential may be used to offset the changes in the NFA.

To investigate the extent to which DNB NFA react to the ECB's policy rate, we substitute the interest rate differential by the ECB's policy rate in equation (2). The estimation results

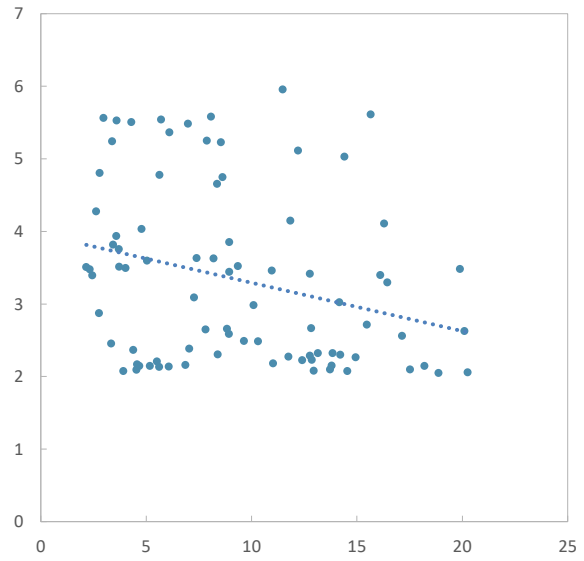
(Appendix VI, Table 2) suggest that DNB NFA are also responsive to the ECB's policy rate and that the relationship between both variables is negative.

We then estimate equations (3) and (4) for Denmark. The regression results (Appendix VI, Tables 3 and 4) suggest that an increase in the NFA (change) results in a decrease in DNB monetary policy lending (change) and an increase in the volume of its CDs (change)[16]. The results that are both statistically significant (p-value < 0.01) suggest that the DNB sterilizes the effect of the NFA on bank reserves by adjusting the volume of its monetary operations.

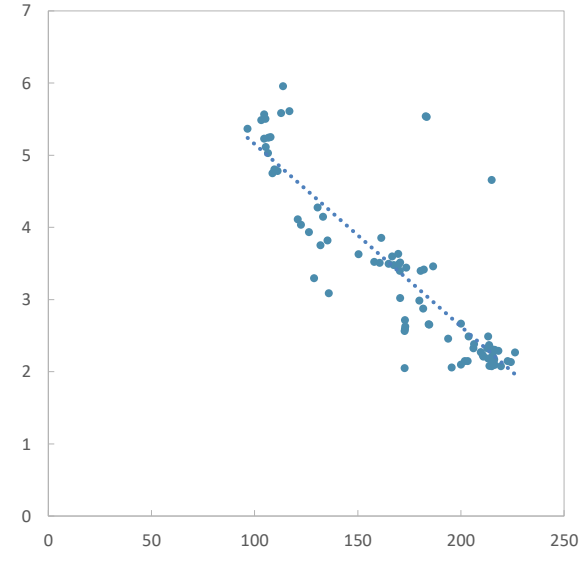
Finally, we plot the reserve supply curve for Denmark to investigate whether the theory matches the empirical evidence. We found that the reserve supply curve was downward sloping during the periods 2000–06 and 2007–14, possibly indicating that the NFA were driving bank reserves and money market rates (Figures 19 and 20). It then becomes upward sloping in 2015–17 (Figure 21).

Figure 19. Denmark—Reserves Supply Curve (2000–06)

19.1 O/N Interbank Rate (Y axis) and Bank Reserves (X axis) 2000–06



19.2 O/N Interbank Rate (Y axis) and NFA (X axis) 2000–06

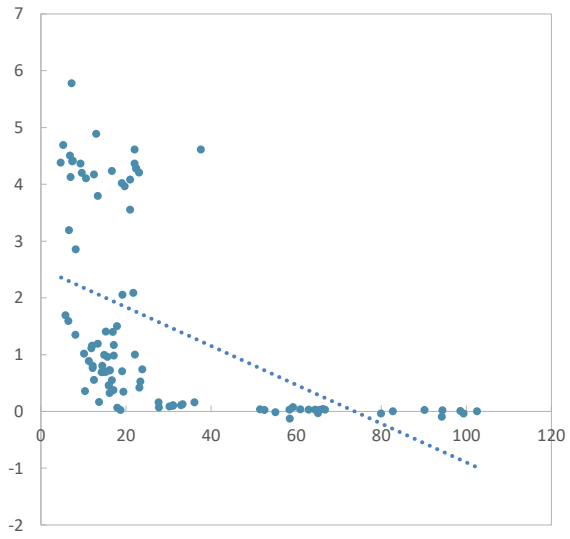


Sources: DNB website and authors' calculations.

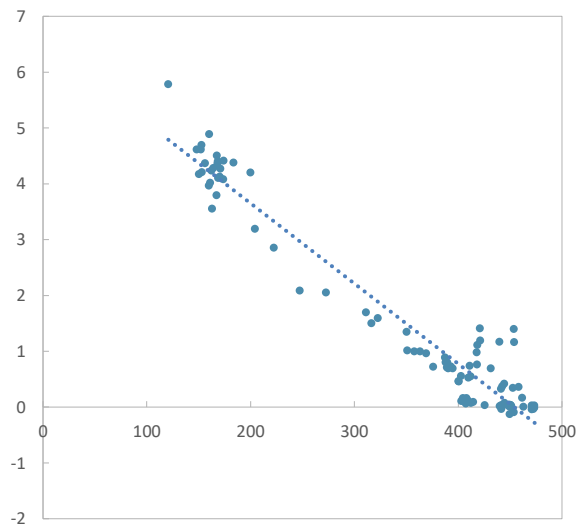
[16] Only statistically significant variables are displayed.

Figure 20. Denmark—Reserves Supply Curve (2007–14)

20.1 O/N Interbank Rate (Y axis) and Bank Reserves (X axis) 2007–14



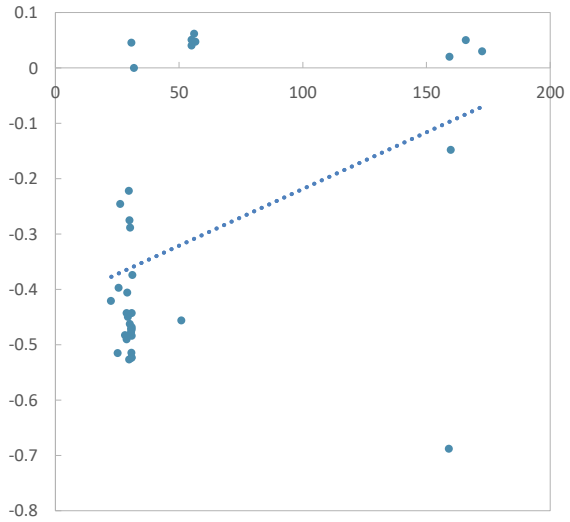
20.2 O/N Interbank Rate (Y axis) and NFA (X axis) 2007–14



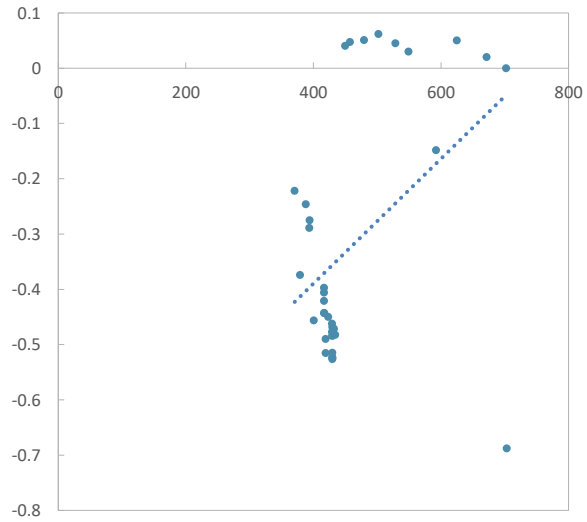
Source: DNB website and authors' calculations.

Figure 21. Denmark—Reserves Supply Curve (2015–17)

21.1 Interbank Rates (Y axis) Bank Reserves (X axis) 2015–17



21.2 Interbank Rates (Y axis) NFA (X axis) 2015–17



Source: DNB website and authors' calculations.

B. Hong Kong SAR

The Hong Kong SAR Dollar (HKD) is officially linked to the USD at the rate of 7.8 HKD per one USD. This linked exchange rate system was adopted in October 17, 1983. It is a currency board system that requires both the stock and flow of the monetary base to be fully backed by foreign reserves. This means that any change in the monetary base is fully matched by a corresponding change in foreign reserves at a fixed exchange rate. Under the Linked Exchange Rate System in Hong Kong SAR, the change in the monetary base is a passive process (upon the request of banks). The resources for this backing are kept in the Hong Kong SAR Exchange Fund. Main items of the Hong Kong SAR Exchange Fund abridged balance sheet are presented in Figure 3.2 above. The HKMA does not have a mandate for price stability. Under the Exchange Fund Ordinance, the overriding objective is exchange rate stability. However, the IMF AREAER 2017 classifies Hong Kong SAR *de facto* monetary policy framework as an exchange rate anchor.[17]

In Hong Kong SAR, the monetary base includes:

- Certificates of Indebtedness, which exactly back the banknotes issued by the note-issuing banks;
- Government-issued notes and coins in circulation;
- Aggregate balance, which is the sum of the balances of the clearing accounts of banks kept with the HKMA;
- Exchange Fund bills and notes, which are issued by the HKMA.

Most banknotes in Hong Kong SAR are issued by three note-issuing banks. When they issue banknotes, they are required by law to purchase Certificates of Indebtedness, which serve as backing for the banknotes issued, by submitting an equivalent amount of USD, at the rate of HKD 7.80 per one US dollar, to the HKMA for the account of the Exchange Fund. HKD banknotes are therefore fully backed by USD held by the Exchange Fund. Conversely, when HKD banknotes are withdrawn from circulation, Certificates of Indebtedness are redeemed, and the note-issuing banks receive an equivalent amount of USD from the Exchange Fund. In the case of notes and coins issued by the government through the HKMA, transactions between the HKMA and the agent bank responsible for storing and distributing the notes and coins to the public are also settled against USD at a rate of HKD 7.8 per one USD.

Under the Hong Kong SAR Currency Board system, it is interest rates rather than the exchange rate that adjust to inflows or outflows of funds. The monetary base increases when the foreign currency (that is, USD) is sold to the Currency Board for the domestic currency. It contracts when the foreign currency is bought from the Currency Board. The expansion or

[17] The IMF AREAER defines exchange rate anchors as frameworks where "The monetary authority buys or sells foreign exchange to maintain the exchange rate at its predetermined level or within a range. The exchange rate thus serves as the nominal anchor or intermediate target of monetary policy. These frameworks are associated with exchange rate arrangements with no separate legal tender, currency board arrangements, pegs (or stabilized arrangements) with or without bands, crawling pegs (or crawl-like arrangements), and other managed arrangements."

contraction in the monetary base causes interest rates for the domestic currency to fall or rise respectively, creating the monetary conditions that are expected to counteract the original capital movement, while the exchange rate remains stable. This process is similar to the price-specie flow mechanism as described and revisited in Section II.

However, to reduce excessive interest rate volatility, a cushion of liquidity is provided by the discount window facility, through which banks can obtain O/N liquidity from the HKMA by arranging repurchase agreements using Exchange Fund paper and other eligible securities as collateral. The base rate, as explained earlier, is the interest rate forming the foundation upon which the discount rates are computed.

Before estimating equations (2), (3), and (4) for Hong Kong SAR, we rearrange the balance sheet items: first, we sum the government-issued notes and coins in circulation, and the Certificates of Indebtedness that back the banknotes issued by banks, to form one series for the CiC. Second, we consider the Exchange Fund bills and notes, as a proxy of the liquidity absorption operations and the discount widow as the liquidity-providing operation; we use the base rate as the policy rate. Finally, we use the placements by fiscal reserves as a proxy for the government account, and the Hong Kong Exchange Fund FX reserves as a proxy for the NFA.

We first estimate equation (2) to test the relationship between the base rate and the NFA in Hong Kong SAR. All the variables used in the regression are in first difference and stationary according to Augmented Dickey-Fuller tests, except DCIC and DGOV. The estimation period for Hong Kong SAR is 2001Q3–2017Q4. We found that the regression coefficient associated to the base rate change (one period ahead) is statistically significant; however, the discount window volume coefficient is not statistically significant.[18] Appendix VII, Table 1 shows the regression results including only significant explanatory variables. The inclusion of only one non-stationary variable (DCIC) limits the risk of spurious regression (DGOV is not statistically significant).

We then estimate equation (3) for Hong Kong SAR and find that none of the explanatory variables is statistically significant. This suggests that the HKMA does not adjust the volume of the discount window to the change in the NFA, and more generally that the discount window is not calibrated according to autonomous factors forecasts.

The regression results are, however, different for Hong Kong SAR Exchange Fund bills and notes (equation [4]): these confirm that an increase in the NFA results in an increase in the volume of Hong Kong SAR Exchange Fund bills and notes issued as presented in Appendix VII, Table 2 (including explanatory variables that are statistically significant only).[19] However, the HKMA has indicated that it does not issue bills and notes to sterilize the effect

[18] According to the HKMA, the significance of base rate does however not imply that it uses the base rate to react to FX reserves.

[19] The inclusion of only one non-stationary variable (DGOV) limits the risk of spurious regression (DCIC is not statistically significant).

of the NFA; the additional supply of short-dated Exchange Fund paper is designed to meet the strong demand for Exchange Fund paper by banks for liquidity management. According to the HKMA, the increase in the supply of Exchange Fund Bills is consistent with the currency board principles, since the additional issuance represents a change in the composition of the monetary base, with a shift from the aggregate balance to Exchange Fund paper. The monetary base remains fully backed by foreign exchange reserves. The issuance of additional Exchange Fund bills are not expected to have a significant impact on liquidity conditions and interest rates.

V. CONCLUSION

In this paper, we presented a theoretical framework for liquidity management under a fixed exchange rate derived from the price-specie flow mechanism. Under this conceptual framework, liquidity management is automatic and does not rely on central bank monetary operations. In the absence of any intervention of the central bank in the money market, the theoretical reserves supply curve is upward sloping; in practice, it depends on FX flows and their responsiveness to the local money market rate. We showed that such conceptual framework could, in some circumstances, generate excessive interest rate volatility due to autonomous factor shocks and reaction of FX flows to changes in liquidity conditions. Therefore, we conclude that liquidity management, inasmuch as it contributes to stabilize short-term rates, has a financial stability function in fixed exchange rate arrangements that goes beyond the traditional monetary policy implementation one.

We then explored the practice of central banks operating under currency boards and conventional pegs and found that: (1) the majority introduced reserve requirements, usually with an approximately one-month averaging period; (2) many of them use short-term OMOs, but not always calibrated according to autonomous factor forecasts; (3) few of them have an interest rate corridor in place; and (4) in some cases, the interest rate is used to offset FX flows.

With the adequate combination of instruments (reserve requirements, interest rate, OMOs, and SFs) and a calibration of OMOs according to autonomous factors' forecasts, central banks operating under fixed exchange rate arrangements and open capital account can achieve the following objectives:

- Offset short-term liquidity shocks, dampen interest rate volatility, and foster money market stability and development;
- Lower the precautionary demand for reserves, funding costs, and lending rates; and
- Build liquidity buffers in good times and contain the buildup of financial stability risks, while releasing liquidity in times of reversals in liquidity conditions (capital outflows or adverse current account shocks).

Appendix I. Interest Rate Setting Mechanism of Countries with Fixed Exchange Rate Arrangements

Exchange Rate Arrangement	Economy/ Monetary Union	Is the central bank steering short-term rate? (Y/N)*	Policy Rate Setting Mechanism
Currency Boards	Bosnia and Herzegovina	N	
	Brunei	N	
	Bulgaria	N	The BIR is set with reference to the LEONIA Plus.
	Djibouti	N	
	ECCU	N	
	Hong Kong SAR	N	The base rate is set with reference to the Fed Fund Target.
Conventional Pegs	Aruba		
	Bahamas	Y	
	Bahrain	Y?	
	Barbados		
	Belize		
	Bhutan	N	
	Cabo Verde		
	CEMAC	N	
	Comoros		
	Curaçao and Sint Maarten		
	Denmark	N?	The lending rate is set with reference to the ECB policy rate.
	Eritrea		
	Fiji	Y	The central bank has an interest rate corridor.
	Iraq		
	Jordan	Y	The central bank has an interest rate corridor.
	Kuwait	Y	
	Lesotho		
	Libya		
	Morocco	Y	Combination of Taylor Rule and UIP condition. The central bank has a standard mid-corridor system.
	Namibia		
	Nepal	N	
	Oman		
	Qatar	Y	
	Salomon Islands	N	
	Samoa	N	
	São Tomé and Principe		
	Saudi Arabia	Y	
	Swaziland		
	Turkmenistan		
	UAE	N	
	Venezuela		
	WAEMU		

(*) "Y" if the central bank has a policy rate and/or a standing facility to drive market rates. A standard mid-corridor system would include OMOs, and O/N standing credit and deposit facilities, and often a reserve requirement mechanism. Reserve requirements only are not sufficient to steer short-term rate ("N").
Sources: AREAER (2016), ISIMP (2013), MOID (2018) in blue, and central banks' available information.

Appendix II. Fixed Exchange Rate Open Market Operations

Exchange Rate Arrangement	Economy/ Monetary Union	Repo and Reverse Repo			
		(Y/N)*	Frequency	Maturity	Auction Type
Currency Boards	Bosnia and Herzegovina	N	-	-	-
	Brunei	N	-	-	-
	Bulgaria	N	-	-	-
	Djibouti	N	-	-	-
	ECCU	Y	Irregular	1 week	Uniform price
	Hong Kong SAR	N	-	-	-
Conventional Pegs	Aruba				
	Bahamas	N	-	-	-
	Bahrain				
	Barbados				
	Belize	N	-	-	-
	Bhutan				
	Cabo Verde				
	CEMAC	N	-	-	-
	Comoros	N	-	-	-
	Curaçao and Sint Maarten				
	Denmark				
	Eritrea				
	Fiji				
	Iraq	N	-	-	-
	Jordan	Y	Weekly	1 week, 1 month	Fixed rate, partial allotment
	Kuwait	Y	Irregular	O/N, 1 week, 1 month	Fixed rate, full allotment
	Lesotho	N	-	-	-
	Libya				
	Morocco	Y	Weekly	1 week	Fixed rate, partial allotment
	Namibia	N	-	-	-
	Nepal	Y	Weekly	28 days	Multiple price
	Oman	Y	Weekly	28 days	Multiple price
	Qatar	Y		14-28 days	Uniform price
	Salomon Islands	Y	Monthly		
	Samoa	Y	Never used	182 days	Never used
	São Tomé and Principe				
	Saudi Arabia	N	-	-	-
	Swaziland	N	-	-	-
	Turkmenistan				
	UAE				
	Venezuela				
	WAEMU				

(*) "Y" = Yes; "N" = No; " " = information unclear or unavailable in ISIMP and MOID.

Sources: AREAER (2016), ISIMP (2013), MOID (2018) in blue, and central banks' available information.

Exchange Rate Arrangement	Economy/ Monetary Union	FX Swap			
		(Y/N)*	Frequency	Maturity	Auction/Bilateral
Currency Boards	Bosnia and Herzegovina	N	-	-	-
	Brunei				
	Bulgaria	N	-	-	-
	Djibouti	N	-	-	-
	ECCU	N	-	-	-
	Hong Kong SAR				
Conventional Pegs	Aruba				
	Bahamas	N	-	-	-
	Bahrain	Y	Daily	1 week; 1, 3, and 6 months	Fixed rate, full allotment
	Barbados				
	Belize	N	-	-	-
	Bhutan	N	-	-	-
	Cabo Verde				
	CEMAC	N	-	-	-
	Comoros	N	-	-	-
	Curaçao and Sint Maarten				
	Denmark				
	Eritrea				
	Fiji	N	-	-	-
	Iraq				
	Jordan	Y	Irregular	1 month	Bilateral
	Kuwait	Y	Irregular	2, 3, 4, 5 and 6 months	Bilateral
	Lesotho	N	-	-	-
	Libya				
	Morocco	Y	Irregular	3 months	Fixed rate, full allotment
	Namibia	N	-	-	-
	Nepal	N	-	-	-
	Oman	Y	Irregular	Short-term and long-term	
	Qatar	N	-	-	-
	Salomon Islands	N	-	-	-
	Samoa	N	-	-	-
	São Tomé and Principe				
	Saudi Arabia	N	-	-	-
	Swaziland	N	-	-	-
	Turkmenistan				
	UAE	Y	Daily	1 week to 12 months	Fixed rate, full allotment
	Venezuela	N	-	-	-
	WAEMU				

(*) “Y” = Yes; “N” = No; “ ” = information unclear or unavailable in ISIMP and MOID.

Sources: AREAER (2016), ISIMP (2013), MOID (2018) in blue, and central banks’ available information.

Exchange Rate Arrangement	Economy/ Monetary Union	Collateralized Lending			
		Y/N (*)	Frequency	Maturity	Auction/Bilateral
Currency Boards	Bosnia and Herzegovina	N	-	-	-
	Brunei				
	Bulgaria	N	-	-	-
	Djibouti	N	-	-	-
	ECCU	Y		Up to 1 year	Fixed rate, full allotment
	Hong Kong SAR	N	-	-	-
Conventional Pegs	Aruba				
	Bahamas	N	-	-	-
	Bahrain				
	Barbados				
	Belize	N	-	-	-
	Bhutan	N	-	-	-
	Cabo Verde				
	CEMAC	N	-	-	-
	Comoros	N	-	-	-
	Curaçao and Sint Maarten				
	Denmark	Y		1 week	Fixed rate, full allotment
	Eritrea				
	Fiji	N	-	-	-
	Iraq	N	-	-	-
	Jordan	Y		Up to 1 year	Fixed rate, full allotment
	Kuwait	Y		Up to 6 months	
	Lesotho	N	-	-	-
	Libya				
	Morocco	Y		1 year	Fixed rate, full allotment
	Namibia	Y			
	Nepal	Y	Irregular	6 months	Bilateral
	Oman	Y		26 days	Bilateral
	Qatar	N	-	-	-
	Salomon Islands	N	-	-	-
	Samoa	Y		Not exceeding 21 days within a month	Bilateral
	São Tomé and Principe				
	Saudi Arabia	N	-	-	-
	Swaziland	Y			Bilateral
	Turkmenistan				
	UAE	Y		1 week	Bilateral
	Venezuela	Y			Bilateral
	WAEMU				

(*) “Y” = Yes; “N” = No; “ ” = information unclear or unavailable in ISIMP and MOID.

Sources: AREAER (2016), ISIMP (2013), MOID (2018) in blue, and central banks’ available information.

Exchange Rate Arrangement	Economy/ Monetary Union	Term Deposits (Local currency)			
		Y/N (*)	Frequency	Maturity	Auction/Bilateral
Currency Boards	Bosnia and Herzegovina	N	-	-	-
	Brunei				
	Bulgaria	Y		1 week, 1 month, 3 to 6 months, 12 months	Fixed rate, full allotment
	Djibouti	N	-	-	-
	ECCU	N	-	-	-
	Hong Kong SAR	N	-	-	-
Conventional Pegs	Aruba				
	Bahamas	N	-	-	-
	Bahrain	Y			
	Barbados				
	Belize	N	-	-	-
	Bhutan	N	-	-	-
	Cabo Verde				
	CEMAC	N	-	-	-
	Comoros	N	-	-	-
	Curaçao and Sint Maarten				
	Denmark	N	-	-	-
	Eritrea				
	Fiji	N	-	-	-
	Iraq	Y	-	-	Fixed rate, full allotment
	Jordan				
	Kuwait	Y		1 week, 1 month	Fixed rate, full allotment
	Lesotho	N	-	-	-
	Libya				
	Morocco	N	-	-	-
	Namibia	Y			
	Nepal	Y		Irregular	Bilateral
	Oman	N	-	-	-
	Qatar	Y		O/N to 30 days	Bilateral
	Salomon Islands	N	-	-	-
	Samoa	N	-	-	-
	São Tomé and Principe				
	Saudi Arabia	Y			
	Swaziland	Y			Bilateral
	Turkmenistan				
	UAE	N	-	-	-
	Venezuela	N	-	-	-
	WAEMU				

(*) "Y" = Yes; "N" = No; " " = information unclear or unavailable in ISIMP and MOID.

Sources: AREAER (2016), ISIMP (2013), MOID (2018) in blue, and central banks' available information.

Exchange Rate Arrangement	Economy/ Monetary Union	Central Bank Securities (Local currency)			
		Y/N (*)	Frequency	Maturity	Auction/Bilateral
Currency Boards	Bosnia and Herzegovina	N	-	-	-
	Brunei				
	Bulgaria				
	Djibouti				
	ECCU	N	-	-	-
	Hong Kong SAR	Y		1, 3 to 6 months, 1 year and 2 years	Multiple price
Conventional Pegs	Aruba				
	Bahamas				
	Bahrain				
	Barbados				
	Belize				
	Bhutan	Y		3 to 6 months	Fixed rate, full allotment
	Cabo Verde				
	CEMAC				
	Comoros				
	Curaçao and Sint Maarten				
	Denmark				
	Eritrea				
	Fiji	Y		14 days	Multiple price
	Iraq	Y			
	Jordan	Y		1 week	Fixed rate, partial allotment
	Kuwait	Y		3 to 6 months	Fixed rate, partial allotment
	Lesotho				
	Libya				
	Morocco	N	-	-	-
	Namibia				
	Nepal				
	Oman				
	Qatar	N	-	-	-
	Salomon Islands	Y		1 month	Multiple price
	Samoa	Y		14 days, 1 month, 3 to 6 months, 365 days	Multiple price
	São Tomé and Principe				
	Saudi Arabia	Y		1 week; 1, 3 to 6, and 12 months	Fixed rate, full allotment
	Swaziland				
	Turkmenistan				
	UAE	Y		1 week; 1, 2, 3, 6, 12 months; 2, 5 years	Fixed rate, full allotment
	Venezuela				
	WAEMU				

(*) “Y” = Yes; “N” = No; “ ” = information unclear or unavailable in ISIMP and MOID.

Sources: AREAER (2016), ISIMP (2013), MOID (2018) in blue, and central banks’ available information.

Appendix III. Fixed Exchange Rate Standing Facilities

Exchange Rate Arrangement	Economy/ Monetary Union	O/N SF Credit (*)	O/N SF Deposit (*)
Currency Boards	Bosnia and Herzegovina	N	N
	Brunei	N	N
	Bulgaria	N	N
	Djibouti	N	Y
	ECCU	N	N
	Hong Kong SAR	N	N
Conventional Pegs	Aruba		
	Bahamas	Y	N
	Bahrain		
	Barbados		
	Belize	N	N
	Bhutan	N	N
	Cabo Verde		
	CEMAC	N	N
	Comoros	N	Y
	Curaçao and Sint Maarten		
	Denmark	N	N
	Eritrea		
	Fiji	Y	Y
	Iraq	N	N
	Jordan	Y	Y
	Kuwait	Y	N
	Lesotho	Y	N
	Libya		
	Morocco	Y	Y
	Namibia	N	Y
	Nepal	N	N
	Oman	Y	N
	Qatar	Y	Y
	Salomon Islands	N	N
	Samoa	N	N
	São Tomé and Principe		
	Saudi Arabia	Y	Y
	Swaziland	Y	Y
	Turkmenistan		
	UAE	Y	N
	Venezuela	N	N
	WAEMU		

(*) "Y" = Yes; "N" = No; " " = information unclear or unavailable in ISIMP; "N" if the SF is not O/N.

Sources: AREAER (2016), ISIMP (2013), MOID (2018) in blue, and central banks' available information.

Appendix IV. Fixed Exchange Rate Reserve Requirement Mechanism

Exchange Rate Arrangement	Economy/ Monetary Union	Reserve Requirement (*)	Ratio (percent)	Averaging (*)	Averaging Period	Remuneration (percent)
Currency Boards	Bosnia and Herzegovina	Y	10	Y	10 days	0
	Brunei	Y	6	Y	1 month	0
	Bulgaria	Y	10	Y	1 month	0
	Djibouti	N	-	-	-	-
	ECCU	Y	6	Y	1 week	0
	Hong Kong SAR	N	-	-	-	-
Conventional Pegs	Aruba					
	Bahamas	Y	5	Y	1 month	0
	Bahrain	Y	5	N	-	0
	Barbados					
	Belize	Y	8.5	Y	30 days	0
	Bhutan	Y	10	N	-	0
	Cabo Verde					
	CEMAC	Y				
	Comoros	Y (**)	20	Y	1 month	EONIA – 1.25
	Curaçao and Sint Maarten					
	Denmark	N	-	-	-	-
	Eritrea					
	Fiji	Y	10	Y	1 month	0
	Iraq	Y	15	Y	1 month	0
	Jordan	Y	7	Y	2 weeks	0
	Kuwait	N	-	-	-	-
	Lesotho	Y	3	Y	1 week	0
	Libya					
	Morocco	Y	4	Y	4-5 weeks	0.75
	Namibia	Y	1	Y	1 month	0
	Nepal	Y	5-6	Y	7 days	0
	Oman	Y	5	Y	4-5 weeks	0
	Qatar	Y	4.75	N	-	0
	Salomon Islands	Y	7.50	Y	4 weeks	0
	Samoa	Y	4.50	Y	1 month	0
	São Tomé and Principe					
	Saudi Arabia	Y	4-7	N	-	0
	Swaziland	Y	6	Y	1 week	0
	Turkmenistan					
	UAE	Y	1-14	Y	1 week	0
	Venezuela	Y	17	Y	1 week	0
	WAEMU					

(*) "Y" = Yes; "N" = No; " " =information unclear or unavailable in ISIMP and MOID. Answers concern local currency reserve requirements only.
(**) The reserve requirements are contractual in Comoros.

Source: AREAER (2016), ISIMP (2013), MOID (2018) in blue, and central banks available information.

Appendix V. Fixed Exchange Rate Direct Instruments of Monetary Control

Exchange Rate Arrangement	Economy/ Monetary Union	Interest rate Controls (*)	Credit Ceilings (*)	Directed Credits (*)	Specific Lending Requirements (*)
Currency Boards	Bosnia and Herzegovina	N	N	N	N
	Brunei	Y	Y	N	Y
	Bulgaria	N		N	N
	Djibouti	N	N	N	N
	ECCU	N	N	N	N
	Hong Kong SAR	N	N	N	N
Conventional Pegs	Aruba				
	Bahamas	Y	Y	Y	Y
	Bahrain	N	N		N
	Barbados				
	Belize	Y	N	N	N
	Bhutan	N	N	Y	Y
	Cabo Verde				
	CEMAC	N	N	N	N
	Comoros	Y	N	N	N
	Curaçao and Sint Maarten				
	Denmark	N	N	N	N
	Eritrea				
	Fiji	N	N	Y	N
	Iraq	N	N	N	N
	Jordan	N	N	N	N
	Kuwait	Y	Y	N	N
	Lesotho	N	N	N	N
	Libya				
	Morocco	N	N	N	N
	Namibia	N	N	N	Y
	Nepal	N	Y	Y	Y
	Oman	Y	Y	Y	Y
	Qatar	N	N	N	N
	Salomon Islands	Y	N	N	Y
	Samoa	N	N	N	N
	São Tomé and Principe				
	Saudi Arabia	N	N	N	N
	Swaziland	Y	N	N	Y
	Turkmenistan				
	UAE	N	N	N	Y
	Venezuela	Y	Y	Y	Y
	WAEMU				

(*) "Y" = Yes; "N" = No; " " = information unclear or unavailable in ISIMP and MOID; local currency reserve requirements only.

Sources: AREAER (2016), ISIMP (2013), MOID (2018) in blue, and central banks' available information.

Appendix VI. Denmark—Offset Coefficients Estimates

Table 1. Relationship between DNB NFA and Interest Rate Differential

	Denmark
	Change in the NFA (DNFA)
Interest rate differential at t-3 (IDIFF(-3))	2.695068***
	(1.502025)
Change in Bank reserves (DR)	1.034366*
	(0.023093)
Change in DNB monetary policy lending (DLP)	-1.038834*
	(0.022616)
Change in DNB CDs (DLA)	0.965646*
	(0.019960)
Change in CiC (DCIC)	0.934669*
	(0.282874)
Change in Government Deposits (DGOV)	0.970327*
	(0.017615)
R-squared	0.992165
Adjusted R-squared	0.991543

Sources: ECB and DNB website and authors' calculations.
Note: Dependent variable: Change in the NFA (DNFA). Standard errors in parentheses. * p < 0.01; ** p < 0.05; *** p < 0.1.

Table 2. Relationship between DNB NFA and ECB Policy Rate

	Denmark
	Change in the NFA (DNFA)
Change in ECB policy rate at t-3 (DIF(-3))	-4.930738*
	(1.578297)
Change in Bank reserves (DR)	1.023118*
	(0.022426)
Change in DNB monetary policy lending (DLP)	-1.030796*
	(0.022568)
Change in DNB CDs (DLA)	0.982617*
	(0.019520)
Change in CiC (DCIC)	0.976535*
	(0.272535)
Change in Government Deposits (DGOV)	0.978557*
	(0.016761)
R-squared	0.992886
Adjusted R-squared	0.992312

Sources: ECB and DNB websites and authors' calculations.
Note: Dependent variable: Change in the NFA (DNFA). Standard errors in parentheses. * p < 0.01; ** p < 0.05; *** p < 0.1.

Table 3. Relationship between DNB Monetary Policy Lending and NFA

	Denmark
	Change in DNB monetary policy lending (DLP)
Change in Bank reserves (DR)	0.957952*
	(0.031230)
Change in DNB NFA (DNFA)	-0.930317*
	(0.019455)
Change in DNB CDs (DLA)	0.912844*
	(0.020558)
Change in CiC (DCIC)	0.947734*
	(0.260860)
Change in Government Deposits (DGOV)	0.914373*
	(0.021014)
R-squared	0.976974
Adjusted R-squared	0.975579

Sources: DNB website and authors' calculations.
Note: Dependent variable: Change in DNB monetary policy lending (DLP). Standard errors in parentheses. * p < 0.01; ** p < 0.05; *** p < 0.1.

Table 4. Relationship between DNB CDs Volume and NFA

	Denmark
	Change in DNB CDs Volume (DLA)
Change in Bank reserves (DR)	-1.026867*
	(0.036075)
Change in DNB monetary policy lending (DLP)	1.059994*
	(0.023872)
Change in DNB NFA (DNFA)	1.003091*
	(0.020532)
Change in CiC (DCIC)	-0.964808*
	(0.284106)
Change in Government Deposits (DGOV)	-0.992189*
	(0.017520)
R-squared	0.985630
Adjusted R-squared	0.984759

Sources: DNB website and authors' calculations.
Note: Dependent variable: in DNB CDs Volume (DLA). Standard errors in parentheses. * p < 0.01; ** p < 0.05; *** p < 0.1.

Appendix VII. Hong Kong SAR—Offset Coefficient Estimates

Table 1. Relationship between Hong Kong SAR Exchange Fund FX Reserves and HKMA Base Rate

	Hong Kong SAR
	Change in the NFA (DNFA)
Change in HKMA Base Rate at t-1 (DI(-1))	15597.83**
	(6532.251)
Change in Bank reserves (DR)	0.964590*
	(0.101687)
Change in HKMA Exchange Fund Bills and Notes (DLA)	1.002436*
	(0.125564)
Change in CiC (DCIC)	4.078170*
	(0.501440)
R-squared	0.701477
Adjusted R-squared	0.687032

Sources: HKMA website and authors' calculations.
Note: Dependent variable: Change in the NFA (DNFA). Standard errors in parentheses. * p < 0.01; ** p < 0.05; *** p < 0.1.

Table 2. Relationship between Hong Kong SAR Exchange Fund Bills and Notes and FX Reserves

	Hong Kong SAR
	Change in Exchange Fund Bills and Notes (DLA)
Change in Bank reserves (DR)	-0.331331*
	(0.079627)
Change in HKMA NFA (DNFA)	0.418733*
	(0.043389)
Change in Government Deposits (DGOV)	-0.159675**
	(0.064356)
R-squared	0.499424
Adjusted R-squared	0.483781

Sources: HKMA website and authors' calculations.
Note: Dependent variable: Change in HKMA Certificates of Indebtedness volume (DLA). Standard errors in parentheses.
* p < 0.01; ** p < 0.05; *** p < 0.1.

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