Breaking the Trilemma: Seigniorage and Endogenous Remittances

Abstract

Central banks operating under an exchange rate peg and free capital mobility lack the autonomy to set domestic policy rates. We show that this constraint is not absolute, because imperfect substitutability between financial assets and central bank reserves creates new policy space. Incorporating the central bank's balance sheet and payment flows in a small open economy model with a dollar peg, we examine how central bank profit rebates to the treasury can serve as a tool to uphold the peg amidst large US rate hikes. By moderately adjusting profit rebates, the central bank can drive a wedge between domestic policy rates and nominal returns of financial assets, providing a buffer against external shocks. We endogenize this wedge to relax the trilemma and enhance monetary autonomy of small open economies.

Keywords: Central bank profits, exchange rate stability, monetary autonomy, payment systems, monetary policy transmissions

JEL Codes: E42, E58, F33, G21

1 Introduction

The international trilemma, formalized by Fleming (1962) and Mundell (1963), suggests that countries operating under a fixed exchange rate regime and free capital flows cannot set their monetary policy rates autonomously. Extensive empirical evidence supports its implications (see e.g., Shambaugh, 2004; Obstfeld, Shambaugh and Taylor, 2005; Miniane and Rogers, 2007; Aizenman, Chinn and Ito, 2010; Bluedorn and Bowdler, 2010; Klein and Shambaugh, 2015). This trade-off becomes especially challenging for small open economies under heightened exposure to foreign capital flows and global interest rate volatility, as they are increasingly affected by the "spillover effects" of US monetary policy (see, e.g., Miranda-Agrippino and Rey, 2020; Chari, Dilts Stedman and Lundblad, 2021; Akinci and Queralto, 2024). This paper contributes to the literature by proposing a novel monetary instrument – using central bank profit rebates – to enhance monetary policy autonomy for small open economies, while simultaneously maintaining exchange rate stability and free capital mobility. Our approach provides a built-in shock absorber for mitigating the effects of US interest rate shocks.

The trilemma is based on the uncovered interest rate parity (UIP) logic: in a small open economy that pegs its nominal exchange rate to the US dollar, a US interest rate hike necessitates a corresponding rise in domestic nominal returns of financial assets to maintain the peg. Consequently, domestic policy rates may rise, risking an economic slowdown. In this paper, while maintaining the UIP for financial assets, we show that there is still policy space to relax the trilemma. This is because *nominal returns of domestic financial assets* and the *domestic policy rate* do not necessarily move in lockstep. We argue that imperfect substitutability between financial assets and central bank reserves creates a wedge between nominal asset turns and the policy rate. This wedge acts as a cushion, enabling the central bank to decouple its policy rate from foreign interest rates, providing a buffer against external shocks. The central bank, by appropriately managing its profit rebates to the treasury, can endogenize this wedge to relax the trilemma. Our modeling approach builds on the existing literature on central bank balance sheets (e.g., Reis, 2013; Del Negro and Sims, 2015; Hall and Reis, 2016), and we extend this body of work by uncovering the previously unexplored potential of central bank profit rebates to create policy space.

Perfect substitutability between money (or reserves) and financial assets rarely holds in reality (see e.g., Nagel, 2016; Krishnamurthy and Li, 2023). In modern banking systems where payments are primarily digital, banks must obtain central bank reserves instead of directly swapping financial assets to settle payments between banks. This underscores that financial assets and central bank reserves are not perfectly substitutable. At its core, the central bank's unique ability to provide reserves generates a certain level of profits through its reserve operations. Though moderate, central bank profits do matter. As shown empirically by Goncharov, Ioannidou and Schmalz (2023) and as supported by our evidence in Section 2, there is a significant association between central bank profits and inflation/nominal exchange rates and it is economically sizable. Our model reveals that central bank profits – more specifically, the central bank profit rebates to the treasury, referred to as "remittances" in the literature – will be the key to relaxing the trilemma constraint on policy rate setting under an exchange rate peg. This mechanism is particularly relevant for emerging market economies with a preference for stabilizing their exchange rates against dominant currencies. Such stabilization efforts are commonplace, as highlighted by Albagli, Ceballos, Claro and Romero (2019), who provide evidence that emerging economy central banks face a trade-off between narrowing their monetary policy differentials vis-à-vis US monetary policy shocks and experiencing currency movements against the US dollar, and that emerging countries display patterns consistent with foreign exchange interventions.

The model features a simple payment system, households and firms, and the public sector. The environment is a small open economy in which international capital flows freely and the domestic central bank implements a nominal exchange rate peg to the US dollar. In a similar spirit to Niepelt (2024*b*), the payment system facilitates payments for agents who need to make purchases in advance of receiving proceeds. The payment system consists of the domestic central bank and commercial banks. Commercial banks write loan contracts and issue demand deposits for firms that need to make immediate payments for working capital (labor) for production before firms receive sales proceeds. To facilitate demand deposit flows between banks, commercial banks obtain reserves from the central bank at an interest rate cost, which is the monetary policy rate. The central bank makes profits through its reserve operations and rebates (some) of these profits as remittances to the treasury. The treasury finances its debt servicing cost through a combination of central bank remittances and taxation. Households own the private sector, decide on consumption and labor, and make portfolio choices. Key to the model is the central bank balance sheet. We model it following Reis (2013) by writing the "resource constraint" of the central bank in terms of the law of motion for central bank liabilities. That is, the central bank raises new funds to repay outstanding liabilities and expand its balance sheet, and the residual funds become its seigniorage profits. We innovate based on Reis (2013) by allowing the central bank to choose how much of the seigniorage profits to rebate to the treasury as remittances and how much to retain as equity. Whenever the central bank chooses to change the remittances, we call it an active remittance policy; when the central bank keeps remittances fixed, we call it a passive remittance policy.

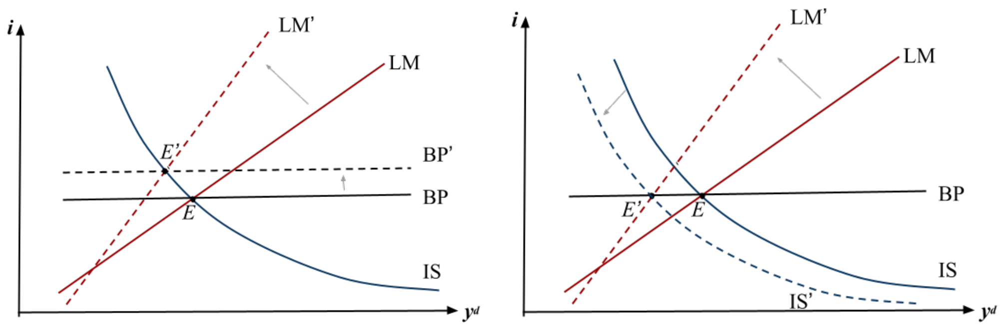
We first establish the existence and uniqueness of the equilibrium and demonstrate the trilemma logic under the passive remittance policy. Assuming fixed remittances and given the domestic policy rate, we find the unique fixed point for the state variable. Based on the existence of the unique fixed point and the reserve market clearing condition, we show that the nominal exchange rate is uniquely determined in equilibrium. This result is obtained by taking the domestic policy rate as given, which means if the nominal exchange rate is priced by markets, the policy rate can be used as an independent policy instrument by the domestic central bank. In contrast, as we fix the nominal exchange rate, we show that the domestic policy rate is uniquely determined in equilibrium, and hence in this case, the domestic central bank cannot set the policy rate independently.

We then consider the scenario of a US interest rate hike to examine how an active remittance policy can relax the trilemma constraint, in comparison with a passive remittance policy. With a passive policy, we show that the domestic central bank must increase its policy rate when the US interest rate shock hits to maintain the exchange rate peg, consistent with the trilemma. The increase in the domestic policy rate raises the borrowing cost of firms' production and therefore decreases output. With an active remittance policy whereby remittances become a choice, we show that the domestic central bank, when foreseeing the US interest rate hike, can reduce remittances to maintain the exchange rate peg, without needing to increase its policy rate and damaging output. However, this result does not imply the violation of UIP for financial assets in the model. The UIP connects the inter-temporal nominal interest rates (nominal returns) on domestic and foreign financial assets, whereas the policy rate is the short-term liquidity cost of reserves. We show analytically that the change in remittances drives a wedge between nominal interest rates of financial assets and the policy rate. Even though the US interest rate hike increases the domestic nominal interest rate on financial assets via the UIP, the wedge acts like a cushion that shields the domestic policy rate from the US rate hikes.

Quantitatively, we calibrate the model to Hong Kong data and solve the full model numerically. We show that our results even hold robustly in the steady states and demonstrate that a relatively small adjustment in remittances can offset significant shifts from US monetary policy while maintaining exchange rate stability. Specifically, we increase the US policy rate from 2% to 6% per annum. In the steady state, with a passive remittance policy, the domestic policy rate has to increase in lockstep, causing quarterly domestic real output to decrease by a staggering 0.76% in the steady state; however, both remittances and the nominal exchange rate remain unchanged. With an active remittance policy, the domestic policy rate remains unchanged but remittances need to go down. Remarkably, the reduction in remittances needed to counter the US policy rate increase and uphold the exchange rate peg is small. The fall in remittances-to-nominal GDP ratio required to uphold the peg amounts to just 0.16% of the nominal GDP, equivalent to 0.11% of central bank assets, and real output incurs zero cost. Since the average ROA (Hong Kong central bank total income/its total assets) over the 2011-2022 period is around 0.46%, the required remittance changes produced by our model are well within the boundaries implied from the central bank income.

To understand the intuition and the transmission mechanism of remittance policies, we derive the IS and LM curves from the model and map the equilibrium conditions into the traditional IS-LM-BP framework. This is illustrated by Figure 1, with the left panel corresponding to a passive remittance policy and the right panel corresponding to an active policy.

Figure 1: Mapping into IS-LM-BP



(a) Passive remittance policy (b) Active remittance policy

The horizontal axis illustrates the demand for output y^d, and the vertical axis illustrates the domestic policy rate i. Locus point E represents before policy changes, and E' represents after policy changes.

When the US interest rate hike lowers the US price level, the domestic central bank needs to lower the domestic price level to maintain the exchange rate peg. Under a passive remittance policy, the domestic central bank lowers prices by tightening monetary policy, which steepens the LM curve and moves it to the left, causing the policy rate to increase (Figure 1a). The increase in the policy rate shifts the BP curve upwards and dampens the demand for output *along* the IS curve. Note that a passive remittance policy does not shift the IS curve. The original locus point E shifts to E' in the left panel, corresponding to a higher policy rate and a lower demand for output. Under an active remittance policy, the central bank reduces profit rebates to the treasury in anticipation of the US interest rate hike. We show that this action tightens the endogenous reserve supply, which also steepens the LM curve and moves it to the left, leading to upward pressure on the policy rate. However, in contrast to a passive remittance policy, this active remittance policy also shifts the IS curve downward, causing downward pressure on the policy rate. This is because the reduction of remittances reduces household liquidity and pushes down aggregate demand. With the remittances appropriately set, the upward and downward pressure on the policy rate cancel out, leaving the policy rate and the BP curve unchanged (Figure 1b).

In both Figure 1a and Figure 1b, the aggregate demand for output decreases. However, the implications for the aggregate supply of output are different. In the passive remittance case, the rise in the policy rate increases the borrowing cost for firms' production, and thus, aggregate supply of output is dampened. In contrast, in the active remittance case, the policy rate does not change, and therefore, the borrowing cost of firms remains unchanged and aggregate supply does not change either. Consequently, in the active case, when aggregate demand equates to aggregate supply to clear the output goods market, equilibrium output does not change, but the fall in aggregate demand manifests in a lower domestic price level, which is desired by the domestic central bank to maintain the exchange rate peg.

We uncover two limitations of an active remittance policy. In practice, central banks of small economies typically acquire sufficient US dollar assets to back their own liabilities, for the exchange rate peg to be infinitely credible in case of currency attacks. This means the central bank balance sheet in our model would face a dollar-backing constraint, which obliges the central bank's domestic liabilities with interest payments to not surpass the value of the central bank's dollar assets with interest proceeds. This constraint ensures that this economy's currency is a "stable-currency" vis-à-vis the US dollar, but it also implies two limitations of our active remittance policy. First, within our setup, we prove that the central bank cannot hold negative equity if the dollar-backing condition has to be satisfied.[1] As changes in remittances lead to changes in the central bank equity, this means the change in remittances faces an upper limit. Without the limit, an increase in remittances can push the central bank equity into negative territory. Second, within this limit, a sufficiently large change in remittances induces the dollar-backing condition to be binding, and the resulting positive shadow price distorts the real economy. In this case, an active remittance policy exerts real effects, in addition to nominal effects, and therefore, the central bank cannot use an active remittance policy to maintain the exchange rate peg without affecting domestic real output.

While an active remittance policy can ease the trilemma constraint, it requires the central bank to directly control the timing and size of profit rebates to the treasury, which may face implementation challenges in practice. To address this, we propose that advances in financial technology such as central bank digital currencies (CBDCs), could offer an indirect means of implementing an active remittance policy. Assuming households derive convenience benefits from a CBDC, the central bank could issue a fixed quantity of a CBDC while setting a periodic usage fee. This fee can be negative, in which case it is a subsidy. We demonstrate that the central bank can choose the fee subject to an upper bound, rather than directly choosing remittances, to ensure exchange rate stability while insulating domestic policy rates

[1]In practice, we have seen the Fed in a position of negative equity by creating the deferred asset entry, but the Fed's monetary policy is not constrained by exchange rate pegs.

from foreign interest rate shocks. Notably, a decrease (an increase) in the US price level can be offset by an increase (a decrease) in the fee contemporaneously. However, we show that a low level of convenience benefits arising from introducing a CBDC, or low levels of central bank profits, would limit the efficacy of setting the fee to relax the trilemma.

Related literature This paper is closely related to the literature that studies central bank balance sheets and the nexus between the central bank and the treasury (see e.g., Berriel and Bhattarai, 2009; Curdia and Woodford, 2011; Reis, 2013; Del Negro and Sims, 2015; Miles and Schanz, 2014; Hall and Reis, 2016). We build on the framework of Reis (2013) to endogenize the central bank profit rebates to the treasury and relax the trilemma rigidity. Del Negro and Sims (2015) show that the central bank's ability to control inflation is impaired without fiscal support, defined as the commitment by the treasury to recapitalize the central bank if necessary. Our model reflects this insight. In our small open economy, although the central bank respects its dollar-backing condition, satisfying this condition boils down to the central bank having sufficient capital. The importance of central bank capital to issue a stable currency is also studied both empirically and theoretically in Bolt, Frost, Shin and Wierts (2024).[2] Miles and Schanz (2014) focus on the size and composition of central bank balance sheets and establish that the effect of asset purchases depends on how fiscal policy is implemented. Berriel and Bhattarai (2009) introduce a budget constraint of the central bank while not permitting transfers from the treasury and analyze optimal monetary policy. This paper contributes to this literature by zooming in on central bank profit rebates and emphasizes their liquidity effects.

This paper also relates to the literature on money and near-money assets (see e.g., Gorton, Lewellen and Metrick, 2012; Krishnamurthy and Vissing-Jorgensen, 2012; Greenwood, Hanson and Stein, 2015; Du, Im and Schreger, 2018; Kacperczyk, Perignon and Vuillemey, 2021; Infante, 2020). For instance, Nagel (2016) examines the opportunity cost of money and time-varying liquidity premia of near-money assets and uncovers a liquidity premium when the elasticity of substitution between money and assets is high. Krishnamurthy and Li (2023) estimate the liquidity premium of bank-created money, shadow-bank money, and Treasury bonds. This paper contributes to this literature by providing a micro-foundation for the liquidity premium via central bank balance sheets and profits: due to the imperfect substitution between reserves and assets, the change in remittances drives a wedge between asset returns and policy rates, and the inverse of this wedge captures the liquidity premium. In our setup, the central bank chooses this wedge to endogenously influence the "money-ness" of financial assets to suit its policy objective.

[2] Recently, new forms of private money have emerged as stablecoins, and they are usually backed by reserves and denominated in fiat currency. See the analysis in Gorton, Klee, Ross, Ross and Vardoulakis (2022); d'Avernas, Maurin and Vandeweyer (2022) for examples.

Furthermore, in this paper reserves and demand deposits are modeled as nominal contracts endogenously issued against credit, reflecting a financing view of money that banks create funding liquidity by extending credit. In the finance literature, Donaldson, Piacentino and Thakor (2018) develop a theory of banking to explain how modern banks create funding liquidity and why they combine lending and liquidity creation within the same institution. Gersbach and Zelzner (2022) provide a rationale for banks funding liquidity creation in the current monetary system. Berger and Bouwman (2009) and Thakor and Yu (2023) provide empirical evidence for banks' funding liquidity creation against lending. The financing view of money has also been analyzed in detail in dynamic macro models and models on payments (see Wang, 2017; Piazzesi and Schneider, 2018; Bianchi and Bigio, 2022; Goodhart, Tsomocos and Wang, 2023, non-exhaustive). For example, Bianchi and Bigio (2022) develop a dynamic general equilibrium monetary model with interbank market frictions to study the credit channel of monetary policy and liquidity risks. They emphasize interbank friction and the transmission of monetary policy through a liquidity premium. We abstract from interbank market frictions to focus on the role of central bank profit rebates in exchange rate targeting. Regarding payment systems, similar to Niepelt (2024*b*), we model the payment system that rests on but enriches the standard "cash-in-advance" models. However, unlike Niepelt (2024*b*), our focus is on the central bank's nominal profits generated via the payment system, while Niepelt (2024*b*) examines more generally how various payment system frictions affect prices and output.

Relatedly, this paper connects with the literature about the effect of liquidity and transaction demand for money on nominal exchange rate dynamics. Engel (2016) embeds liquidity risks within an open-economy model to account for exchange rate dynamics observed in the data. Engel and Wu (2023) find that the liquidity yield on government bonds can explain nominal exchange rate movements. Bianchi, Bigio and Engel (2021) develop a theory of exchange rate fluctuations arising from financial institutions' demand for dollar liquid assets. Itskhoki and Mukhin (2023) develop a general policy framework that features nominal rigidities and financial frictions to endogenize a managed float/crawling peg as the optimal exchange rate policy. This paper complements this literature by deriving the liquidity premium or illiquidity discount of financial assets through central bank profit rebates, and it shows how these profit rebates affect exchange rate determination.

The rest of the paper is organized as follows. In Section 2, we provide motivational evidence on the relation between central bank profits and inflation/nominal exchange rates. In Section 3, we describe our model and define its equilibrium. In Section 4, we characterize and solve for the equilibrium under both active and passive remittance policies and analyze their respective transmission mechanisms. In Section 5, we extend the model to consider the implementation of the active remittance policy via a CBDC. Section 6 concludes. All proofs that are not in the main manuscript are included in the appendices.

2 Empirical motivation

As our theoretical model puts central bank profits at the center stage for exchange rate policies, we first provide motivational evidence on the relevance of central bank profits for inflation and nominal exchange rates. Goncharov, Ioannidou and Schmalz (2023) empirically show, in a side-analysis, that there is indeed a significant association between central bank profits and inflation. We follow up on their analysis by further empirically analyzing the relation between central bank profits and inflation and extend their analysis by investigating the relation between central bank profits and nominal exchange rate changes.

We follow Goncharov et al. (2023) both in terms of methodology and data sources. Specifically, we estimate the following polynomial distributed lag model:

$$y_{i,t} = \beta Profit_{i,t} + \sum_{s=1}^{n} \left[\beta_s roa^s_{i,t} + \gamma_s roa^s_{i,t} * Profit_{i,t}\right] + \delta z_{i,t} + \alpha_i + \gamma_t + \varepsilon_{i,t}, \quad (1)$$

in which $y_{i,t}$ is either inflation or percentage change in the nominal exchange rate, $Profit_{i,t}$ is an indicator variable equal to 1 if central bank profits are above zero, and zero otherwise for central bank i in year t; $roa_{i,t}$ is the return on assets for central bank i in year t, $z_{i,t}$ is a vector of (time-varying) control variables, and α_i is a set of central bank fixed-effects and γ_i year fixed-effects. The optimal n is an empirical question, and we find that the model fit in terms of AIC is highest with $n = 1$.[3]

We obtain annual central bank data from BankScope ranging from 1994 to 2023. We focus on national central banks and exclude supranational central banks. To calculate roa, we divide central net income by total assets. All other data are retrieved from the World Bank, including inflation, the nominal exchange rate in local currency per US dollar, GDP (nominal in local currency), and an indicator variable equal to 1 when country i is considered low-income in period t and zero otherwise. Obviously, not all data are available for all countries and years, but our data used in the regression model have 1,021 observations spanning 109 countries.[4] We winsorize GDP growth, roa, exchange rate return dFX, and inflation at the 5 and 95% levels.

From Table 1, the average inflation is calculated as 5.8%, ranging from 23 to

[3] This is lower than Goncharov et al. (2023), arguably due to our shorter sample period.

[4] Despite using the same sources, our sample is somewhat smaller than Goncharov et al. (2023). This is caused by the limited central bank data availability in BankScope.

Table 1: Descriptive statistics

	N	Mean	SD	Max	Min	Skewness	Kurtosis
Inflation	3,027	5.781	5.984	23.564	-0.271	1.655	5.234
dFX	3,116	0.032	0.080	0.238	-0.091	1.000	3.662
Profit	3,930	0.916	0.277	1	0	-3.006	10.037
roa	1,271	0.008	0.022	0.062	-0.037	0.457	3.823
Growth	3,416	0.096	0.085	0.311	-0.031	0.898	3.390
LI	3,799	0.196	0.397	1	0	1.529	3.337

This table presents the descriptive statistics for the BankScope (roa, profit) and Worldbank data. dFX is the percentage change in the exchange rate in local currency per US dollar; Profit is 1 if central bank profits are positive and zero otherwise; roa is central bank net income divided by total assets; Growth denotes nominal GDP growth in local currencies, and LI is an indicator variable equal to 1 if a country is ranked low-income according to the World Bank definitions. Inflation, dFX, roa, and growth are winsorized at the 5 and 95% levels.

-0.27%. Interestingly, central bank *roa* is a substantial 0.8% on average, ranging from -3.7% to 6.2%. Profit has a mean of 0.92, implying that approximately 8% of the country-year observations of *roa* are negative.

The estimation results of Equation (1) using inflation as the dependent variable are given in Table 2.

Table 2: Estimation results: Inflation

	(1)	(2)	(3)	(4)
	Inflation	Inflation	Inflation	Inflation
Growth	18.71***	18.70***	18.67***	19.02***
	(3.87)	(3.88)	(3.88)	(3.91)
LI	-1.248	-1.249	-1.258	-1.254
	(-0.74)	(-0.74)	(-0.75)	(-0.75)
Profit	-0.0770		-0.146	0.117
	(-0.28)		(-0.39)	(0.30)
roa		0.238	2.108	-27.77*
		(0.05)	(0.31)	(-1.96)
roa*Profit				39.27**
				(2.08)
N	1,021	1,021	1,021	1,021
adj. R^2	0.682	0.682	0.682	0.683
Country FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

This table presents the estimation results of Equation (1). Standard errors are clustered by country; t statistics in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The estimation results in Table 2 reveal that the profit indicator, by itself, is not significant in Model (1). The same holds for roa in Model (2) as well as when including both Profit and roa in Model (3). However, introducing the interaction between roa and Profit in Model (4) does lay bare the nonlinear relationship between central bank profits and inflation. Specifically, we find that the coefficient on roa in Model (4) is significantly negative, -27.77 (t-statistic -1.96) and the interaction roa*Profit is significantly positive, 39.27 (t-statistic 2.08), with the latter significantly larger than the former (P-value = 0.001). Hence, when central banks experience positive profits, there is a positive relationship between profits and inflation; the marginal effect size in times of positive roa is -27.77 + 39.27 = 11.50. The average roa is equal to 0.008. This leads to an extra inflation effect, ceteris paribus, of 0.0931 + 11.50*0.008 = 0.185% per year. A one standard deviation increase in (positive) roa leads to an increase in inflation of, ceteris paribus, 11.50*0.022 = 0.253%. This is economically sizeable, given the average annual inflation of 5.8% and a standard deviation of 5.98%.

The estimation results of the control variables are consistent with ex-ante expectations and intuition. GDP growth is consistently positive and significantly associated with inflation which is expected given that this is nominal growth. The low-income indicator is negative but insignificant throughout, consistent with the findings in Goncharov et al. (2023).

Similar to the inflation analysis in Table 2, in Table 3 we present the estimation results of Equation (1) using nominal exchange rate changes as the dependent variable.

Table 3: Estimation results: FX

	(1) dFX	(2) dFX	(3) dFX	(4) dFX
Growth	0.136**	0.126**	0.126**	0.135***
	(2.56)	(2.46)	(2.46)	(2.67)
LI	0.012**	0.011*	0.010*	0.011*
	(2.14)	(1.98)	(1.97)	(1.84)
Profit	0.015**		-0.003	0.004
	(2.42)		(-0.41)	(0.45)
roa		0.502***	0.543***	-0.228
		(3.59)	(3.02)	(-0.55)
roa*Profit				1.007**
				(2.05)
N	1,043	1,043	1,043	1,043
adj. R^2	0.381	0.392	0.391	0.396
Country FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

This table presents the estimation results of Equation (1). Standard errors are clustered by country; t statistics in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

The estimation results in Table 3 reveal that the relation between central bank profits and exchange rate changes is stronger than with inflation. The Profit dummy variable, in Model (1), has a significantly positive correlation with exchange rate changes. In Model (2), we observe that roa is also positively associated with central bank profits. Model (3) shows that roa contains more information than the Profit dummy, as the coefficient on roa remains positive and significant after including both terms in the model. The nonlinear relation between central bank profits and exchange rate changes becomes apparent in Model (4). We observe that for negative central bank profits, there is an insignificant relation between central bank profits and foreign exchange rate changes. For positive central bank profits, however, we observe a significantly positive relation between central bank profits and exchange rate changes. The positive effect size for positive profits is again significantly larger than the negative effect size for negative profits; -0.228 + 1.007 = 0.779, with P=0.000. In other words, central bank profits are related to a depreciation of the local currency, which is consistent with the results in Table 2 through the PPP relationship. A one standard deviation increase in (positive) central bank profits leads to a depreciation of the currency of 0.779*0.080 = 6.23%, ceteris paribus. Again, this is economically sizeable given the annual standard deviation of exchange rate changes of 8.0%.

The set of control variables in the foreign exchange equations are also consistent with expectations. Nominal economic growth is significantly associated with exchange rate devaluations. Similarly, low-income countries tend to depreciate against the US dollar, given the significant positive coefficients on LI.

Motivated by the empirical evidence, we now present our model to uncover the monetary transmission mechanism of central bank profits and show how a central bank operating under an exchange rate peg can utilize its profit rebates as an additional instrument to relax the constraints on its domestic policy rate setting.

3 Model

The model is a small open economy in which international capital flows freely and the domestic central bank fixes its nominal exchange rate to the US dollar. The payment system consists of the central bank and commercial banks, and it facilitates digital payment flows for transactions. To allow payments to move between commercial banks' ledgers, the central bank provides reserves to commercial banks and obtains profits through its reserve operations. The central bank also makes profit rebates (or remittances, used interchangeably) to the treasury. The treasury finances its debt servicing cost through a combination of taxes and remittances. We start by describing the payment system and the balance sheets and flow of funds of the public sector, and then we move onto private sector agents.

3.1 Payment systems and the public sector

We focus on digital payments processed via banks' ledgers. To keep the analysis compact, we do not include cash payments, which cannot be traced through banks' ledger systems. Commercial banks write loan contracts to non-bank borrowers who need short-term liquidity for immediate payments. Against these loan contracts, commercial banks issue demand deposits for these borrowers. These deposits move between banks, which necessitates central bank reserves to settle. For instance, when a payer with a demand deposit account at one bank makes a payment to a payee at a different bank, the payer's bank must obtain reserves from the central bank at a cost. After the payer has made the payment, the payer's bank shifts reserves to the payee's bank, so the payer bank's asset size decreases, matched by an equal decrease in its liabilities, namely, the reduction in the payer's demand deposits. As this quantity of reserves now sits on the payee bank's balance sheet, it increases the payee bank's asset size, matched by an equal increase in this bank's liabilities, namely, the increase in the payee's demand deposits.

In sum, to move demand deposits between commercial banks at any point in time, commercial banks obtain reserves at a cost from the central bank. The central bank, through its reserve operations, earns net interest margins, which contribute to its seigniorage profits. The central bank rebates (some) of its profits as remittances to the treasury and accumulates equity. Remittances enter the treasury's intertemporal budget flows.

3.1.1 Domestic central bank

The domestic central bank performs the key function of readily meeting the liquidity (reserve) needs of domestic commercial banks. The central bank supplies reserves M_t endogenously to commercial banks by lending μ_t to them at the interest cost of reserves i_t. This i_t is the commercial banks' liquidity cost of obtaining reserves, taken as the policy rate. This function merits some discussion, because in practice central banks' reserve operations have many layers of institutional features that take various forms.

First, although we model the reserve operation as the central bank fulfilling its role as lender of last resort in that it lends to commercial banks to inject reserves at the interest cost i_t, it is equivalent to modeling the central bank buying nominal assets with the face value η_t at a discounted price $q_t\eta_t$ from the commercial banks. In exchange, commercial banks obtain reserves to satisfy their liquidity needs. The nominal assets η_t are subsequently redeemed by commercial banks after their liquidity needs are fulfilled. Our model extension in Appendix G demonstrates the equivalence of these two modeling approaches. Second, we do not assume that domestic commercial banks are endowed with an exogenous initial reserve balance.

Therefore, they must obtain reserves from the central bank, instead of borrowing and lending reserves amongst each other in the interbank market.[5] Although simple, our approach captures an essential aspect of central bank reserve operations whereby the central bank earns a net interest margin, and the interest rate i_t maps into the net interest margin. Lastly, the central bank reserves are modeled as inside money rather than outside money.[6] This is because reserves are issued endogenously against an offsetting credit μ_t, as in Equation (2).

$$\mu_t = M_t. \tag{2}$$

The repayment of μ_t and the interest payment $\mu_t i_t$ by commercial banks in the future extinguishes reserves from banks' ledger systems.

The domestic central bank has initial equity invested in US dollar assets, whose proceeds become the initial remittances m_{-1} to the treasury. From $t = 0$ onwards, a snapshot of the central bank balance sheet is illustrated in Figure 2. Its asset side consists of US dollar asset F_t^* adjusted by the nominal exchange rate χ_t and loans to commercial banks μ_t, and its liability side consists of central bank notes ϵ_t and domestic reserves M_t, as well as equity E_t. The central bank note ϵ_t is an interest-bearing liability the domestic central bank issues held by global arbitrageurs. It raises funds through ϵ_t to invest in US dollar assets, which back the nominal exchange rate peg to the US dollar.[7]

[5]We assume that domestic commercial banks do not participate in the US reserve markets. This segmentation assumption is plausible because the US central bank does not function as the lender of last resort for these small economy commercial banks. Additionally, even if these banks attempted to exchange their domestic reserves for US reserves in such markets, there would likely be little demand for their reserves outside of their home country. This segmentation creates limits to arbitrage in the reserve markets, which can be modeled à la Gabaix and Maggiori (2015). The presence of large global banks does not eliminate these limits to arbitrage or strip the domestic central bank's ability to earn profits, as long as some domestic reserves must be used for interbank settlements by stipulation. If these arbitrage limits were removed, there would be no distinction between domestic and foreign reserves, and exchange rate regimes would become irrelevant. As shown empirically by Obstfeld, Ostry and Qureshi (2019), even in the presence of large global banks, exchange rate regimes still matter for small open economies, and exchange rate flexibility dampens the magnitude of cross-border transmission to the domestic financial sector and domestic economy.

[6]Based on the literature on money in general equilibrium with incomplete markets (see e.g., Dubey and Geanakoplos, 1992; Drèze and Polemarchakis, 2001; Dubey and Geanakoplos, 2003; Tsomocos, 2003; Dubey and Geanakoplos, 2006), *inside money* refers to money issued endogenously against an offsetting credit whose repayment guarantees money's departure, and *outside money* refers to money that enters the system free and clear of any offsetting obligations.

[7]For example, Hong Kong has a currency board system, and the central bank notes issued by the Hong Kong Monetary Authority are called Exchange Fund Bills and Notes, or EFBNs. Suppose the central bank issues zero central bank notes, then it would have no new funds to invest in US dollar assets. In case of demand to convert the central bank reserves to the US dollar (since the peg implies convertibility), the central bank may have to deplete its equity.

Figure 2: Stylised Central Bank Balance Sheet with Exchange Rate Pegs

χF^*: US dollar assets	ϵ: central bank notes
μ: loans to domestic commercial banks	M: domestic reserves
	E: Equity

Balance sheet accounting takes the following form in Equation (3), which says assets equal the sum of liabilities and equity.

$$\chi_t F_t^* + \mu_t = \epsilon_t + M_t + E_t. \tag{3}$$

Furthermore, in practice small economy central banks typically acquire sufficient US dollar assets as foreign reserves to back their own liabilities, for the purpose of deterring speculative currency attacks. This is described in (4), which we call the dollar-backing condition. Let $r_t^* \equiv$ the inter-temporal nominal interest rate of the US dollar assets, and $r_t \equiv$ the inter-temporal nominal interest rate of the central bank notes, which is the same as that on domestic government bonds due to non-arbitrage. The left-hand side of (4) is the domestic liabilities with interest payments, which should not exceed the value of the central bank's dollar assets with interest proceeds, captured by the right-hand side. For now, we assume the dollar-backing condition is non-binding. That is, the shadow price of (4) $\eta_t = 0$.

$$M_t + \epsilon_t(1 + r_t) \leq \chi_t F_t^*(1 + r_t^*). \tag{4}$$

Remark: As we will soon demonstrate, the key results and mechanisms of our model do not rely on the dollar-backing condition (4). This condition is introduced to ensure that the peg to the US dollar remains fully credible, particularly in the event of currency attacks by speculators seeking to exchange M_t for US dollar assets. This means the domestic central bank holds sufficient US dollar assets as foreign reserves in case of a run on domestic central bank money. We will shortly show that whether this condition holds depends on the level of central bank equity, reflecting the insight from Bolt et al. (2024). Imposing this condition allows us to outline the limitations of our proposed channel, as we analyze in Section 4.4.

As in Reis (2013), using the central bank balance sheet, we can write the law of motion for the central bank liabilities as

$$\underbrace{\epsilon_{t+1} + M_{t+1}}_{\text{raise new funds}} = \underbrace{\epsilon_t(1+r_t) + M_t}_{\textit{pay for outstanding liabilities}} + \underbrace{[\mu_{t+1} - (1+i_t)\mu_t] + \chi_t[F^*_{t+1} - F^*_t(1+r^*_t)]}_{\textit{expand balance sheets}} + z_t + \underbrace{S_t}_{\textit{seigniorage}} \tag{5}$$

at all dates, where z_t are exogenous nominal expenses that capture costs such as those associated with dollar liquidity swap lines and all other operating expenses. The first two terms of the left-hand side raise new funds through two ways, one through issuing interest-bearing central bank notes and the other through issuing non-interest-bearing domestic reserves. The first two terms of the right-hand side refer to the repayment of outstanding liabilities, the third and fourth terms refer to the central bank expanding its balance sheet through loans to domestic banks and US dollar assets. The central bank essentially raises new funds to expand its balance sheet and pay for the outstanding liabilities and all other expenses. The residual funds become its seigniorage profits S_t. The law of motion of central bank capital is thus

$$E_{t+1} = E_t + S_t - m_t, \tag{6}$$

where m_t are the remittances the central bank rebates to the treasury.

3.1.2 Payment systems and banks

A key part of the payment system is the commercial banking sector. We model the commercial bank sector by focusing on its payment function. At the beginning of t, the commercial bank sector lends loans L_t to firms that need non-interest-bearing demand deposits for immediate payments for working capital. Against L_t, demand deposits D_t are issued. At the end of t, firms complete production and sell output to obtain money, which is used to repay loans L_t with interest payments $L_t i^l_t$ to the banks. Since demand deposits are non-interest-bearing, the working capital loan rate i^l_t is the commercial banks' marginal benefit of facilitating payments.

At any point in time, there may be a reshuffling of demand deposits between banks, as discussed. We assume a fraction v ($v \in (0, 1]$) of demand deposits move across banks' ledgers.[8] To move across banks' ledgers freely, they require reserve

[8]Note that v does not map into the reserves-to-total deposits ratio in practice. In our benchmark model the deposits D_t are only demand deposits since our focus is on short-term payment flows, but banks can also fund themselves with large quantities of longer term time deposits $\bar{D}_t$, as we model in the extension in Appendix G. The reserves-to-total deposits ratio should be $M_t/(D_t + \bar{D}_t) = v/(1 + \bar{D}_t/D_t)$, which is much smaller than v. In Appendix G, when we extend the model to allow banks to invest in inter-temporal financial assets by funding themselves with interest-bearing inter-temporal time deposits, we show that our model mechanism still carries through.

backing:

$$vD_t = M_t. \tag{7}$$

As the cost of reserves is i_t, the marginal cost of facilitating payments is thus vi_t. Commercial banks' optimality condition is that their marginal benefit of facilitating payments equals the marginal cost. Lemma 1 summarizes this point, with the proof provided in Appendix A.

Lemma 1. *In equilibrium, the policy rate passes through positively to the loan rate as in* (8)

$$i_t^l = vi_t. \tag{8}$$

The strength of passthrough depends on v. In the limit when v approaches zero, which implies that deposits reshuffling requires almost no reserves, the policy rate ceases to pass through to the loan rate. An extensive literature exists on how monetary policy rates are transmitted through the banking system, which studies frictions beyond the scope of our model, for example, moral hazard (see Martinez-Miera and Repullo, 2017), banks' market power (see Wang, Whited, Wu and Xiao, 2022), interbank frictions (see Bianchi and Bigio, 2022), dealer market power and OTC intermediation (see Eisenschmidt, Ma and Zhang, 2024), and default risks (see Goodhart, Tsomocos and Wang, 2023), to name a few. All these frictions will affect the monetary transmission mechanism, which may lead to an imperfect passthrough of policy rates to loan rates. Nevertheless, what is crucial in our analysis is that the monetary policy rate passes through positively to the loan rate, which is captured by the equilibrium condition (8).

3.1.3 Treasury

The treasury finances its debt servicing cost $(1+r_{t-1})B_{t-1} - B_t$ through taxes T_t and central bank remittances m_{t-1} from the previous period. Its inter-temporal budget flow is expressed in (9).

$$(1 + r_{t-1})B_{t-1} - B_t = T_t + m_{t-1}. \tag{9}$$

The existing related literature typically has the government budget constraint as $(1 + r_{t-1})B_{t-1} - B_t = T_t + S_{t-1}$, which assumes the central bank rebates all its seigniorage profits S_{t-1} to the treasury. In practice, this need not be the case. In our setup, because the central bank can accumulate equity, the seigniorage S_t does not need to equal remittances m_t. This deviation is central to our model and allows us to investigate both the nominal and real effects of remittance policies through liquidity channels. Intriguingly, the equilibrium consequences, as we shall shortly see, will turn out to be non-trivial.

3.2 Private agents

Private agents include domestic firms and households. Firms borrow money from banks to make payments for the working capital, i.e., labor, to households before production, in line with the literature on the working capital liquidity-in-advance constraints (see e.g., Christiano et al., 2005; Ravenna and Walsh, 2006). After production, firms sell output to repay bank loans. Households supply labor and also make consumption and portfolio choices.

3.2.1 Domestic Firms

Domestic firms are the non-bank private sector borrowers in the economy. At the beginning of t, they have no monetary endowment, so they enter loan contracts L_t with commercial banks at the interest cost i_t^l to obtain demand deposits D_t to make immediate purchases of labor n_t from households. This payment transaction happens before firms receive money from selling output. That is,

$$P_t w_t n_t = D_t, \tag{10}$$

where P_t is the price level, and w_t is the real wage. Equation (10) is the transaction demand for money. As with reserves, demand deposits are modeled as inside money. The commercial banks issue D_t against loan contract L_t, i.e., $L_t = D_t$. Firms then produce according to $y_t = A_t n_t$ where A_t is the total factor productivity (TFP). After production, firms sell outputs to receive money in their demand deposit accounts, and they use the money to repay loans plus interest payment of $L_t(1 + i_t^l)$. The repayment of loans extinguishes the inside money, i.e., demand deposits (D_t), from commercial banks' ledger systems. Firms' nominal profits are expressed as follows:

$$\Omega_t^f = P_t y_t - (1 + r_t^l)L_t. \tag{11}$$

Firms choose y_t, n_t, L_t, and D_t to maximize (11) subject to $L_t = D_t$, (10), and $y_t = A_t n_t$. The first-order conditions give rise to the real wage equation below

$$w_t = \frac{A_t}{1 + i_t^l}. \tag{12}$$

Substituting in (8), (12) can be expressed as

$$w_t = \frac{A_t}{1 + v i_t}, \tag{13}$$

which says an increase in the policy rate reduces real wages, and vice versa.

3.2.2 Households

The households' problem is fairly standard. A continuum of households maximize their utility function as follows

$$\sum_{t=0}^{\infty} \beta^t \Big[\log(c_t) - \zeta \frac{n_t^{1+\phi}}{1+\phi}\Big], \tag{14}$$

where c_t denotes consumption in period t, $\beta \in (0,1)$ is the discount factor, ϕ is the inverse of the Frisch elasticity of labor supply, and ζ is a scaler. Households trade a portfolio of nominal government bonds B_t and US dollar assets $F^*_{h,t}$. Furthermore, households earn demand deposits D_t by supplying labor, i.e., $D_t = W_t n_t$, where W_t is the nominal wage. Households own the private sectors, receiving nominal profits Ω_t from firms and banks. Their sequential budget flow is

$$P_t c_t + B_t + \chi_t F^*_{h,t} + T_t = (1 + r_{t-1})B_{t-1} + \chi_t(1 + r^*_{t-1})F^*_{h,t-1} + W_t n_t + \Omega_t. \tag{15}$$

Households choose paths of consumption, labor, and asset holdings to maximize the lifetime utility function (14) subject to the budget constraint (15). The optimality conditions are given by the Euler equations (16) and (17), labor supply schedule (18), and the transversality condition $\lim_{t\to\infty} \beta^t[\frac{1}{c_t}\frac{B_t+\chi_t F^*_{h,t}}{P_t}] = 0$

$$1 + r_t = \beta^{-1}\frac{c_{t+1}}{c_t}\Pi_{t+1}, \tag{16}$$

$$1 + r^*_t = \beta^{-1}\frac{c_{t+1}\chi_t}{c_t\chi_{t+1}}\Pi_{t+1}, \tag{17}$$

$$w_t = \zeta n_t^{\phi} c_t, \tag{18}$$

where Π_{t+1} is the gross inflation rate. Letting $\Delta\chi_{t+1} \equiv \frac{\chi_{t+1}}{\chi_t}$, the change of nominal exchange rates, Equations (16) and (17) lead to the uncovered interest rate parity condition

$$1 + r^*_t = (1 + r_t)(\Delta\chi_{t+1})^{-1}. \tag{19}$$

This means that as the inter-temporal interest rate on US assets r^*_t increases, the inter-temporal interest rate on domestic financial assets r_t has to increase by the same amount to ensure the exchange rate remains unchanged.

Furthermore, the US nominal interest rate in (17) can be rewritten as

$$\begin{aligned} 1 + r^*_t &= \beta^{-1}\frac{c_{t+1}}{c_t}\frac{\Pi_{t+1}}{\Delta\chi_{t+1}} \\ &= \beta^{-1}\frac{c_{t+1}}{c_t}\Pi^*_{t+1}. \end{aligned}$$

Let ρ^*_t be the real interest rate of the US asset. The nominal returns r^*_t and real interest rate ρ^*_t will both rise in response to a rise the US policy rate, so long as

US monetary policy is non-neutral. Together with the Fisher equation $1 + r_t^* = (1 + \rho_t^*)\Pi_{t+1}^*$, the Euler Equation (17) can be expressed as

$$1 + \rho_t^* = \beta^{-1}\frac{c_{t+1}}{c_t}. \tag{20}$$

Equation (20) says that the US real interest rate influences domestic consumption plans. This is intuitive, because the small open economy takes ρ_t^* as given and does not influence the determination of US interest rates.

Combining (13) and (18), we have $\frac{A_t}{1+vi_t} = \zeta n_t^{\phi} c_t$, which suggests that a change in the intra-period policy rate affects labor and consumption plans. Moreover, as we combine (7), (10), and (13) to obtain

$$\frac{M_t}{P_t} = \frac{vA_t n_t}{1 + vi_t}, \tag{21}$$

we can see that the change in the policy rate also affects the real money balances and labor.

Now we can combine households' optimality condition (19) with the exchange rate peg $\chi_t = \chi$, as well as the reserve creation equation (2) to simplify the central bank's balance sheet accounting. The balance sheet equation (3) and the dollar-backing condition (4) are thus re-expressed as

$$\chi F_t - \epsilon_t = E_t;$$
$$\chi F_t - \epsilon_t \geq \frac{M_t}{1 + r_t}.$$

The above two conditions imply that the dollar-backing condition boils down to the relationship between the reserves the central bank creates M_t, the nominal return of domestic assets r_t, and central bank equity, i.e., $E_t \geq \frac{M_t}{1+r_t}$. If the central bank equity is sufficiently large, the dollar-backing condition is non-binding, but with a sufficiently low level of equity, the dollar-backing condition may become binding.

3.3 Equilibrium

We define the equilibrium as a sequence of prices of $P_t, w_t, i_t, i_t^l, r_t$, and quantities of $y_t, c_t, n_t, \mu_t, M_t, L_t, D_t, F_t^*, F_{h,t}^*, T_t, E_t, S_t$, and given fixed nominal exchange rate $\chi_t = \chi$, remittance m_t, domestic government bond supply B_t, central bank notes ϵ_t, US interest rates r_t^*, ρ_t^*, and central bank balance sheet accounting, such that agents maximize subject to flow of funds and budget constraints, and labor market, domestic reserve market, domestic asset markets and goods market clear.

Typically, given the exchange rate peg $\chi_t = \chi$, the domestic central bank cannot set its policy rate i_t freely. To see why this may be the case and to explore whether this is categorically true in all cases, we start with some observations of the output market clearing condition (22). We then make use of the payment flows of all agents and the output market clearing condition to uncover the relationship between remittances, endogenous reserves, and the policy rate. This will allow us to formally establish the equilibrium relationship between the policy rate i_t and the nominal determinacy of domestic price level P_t and in turn the nominal exchange rate χ_t.

We start with the output market clearing condition (22). The left-hand side is consumption plus net investment in US dollar assets in consumption units, and the right-hand side is output.

$$c_t + \frac{1}{P_t}\chi_t(F^*_{h,t} - (1 + r^*_{t-1})F^*_{h,t-1}) = y_t. \tag{22}$$

Let $x_t \equiv y_t - c_t$, which is net exports or current account balance, and let $df_{h,t} \equiv -\chi_t(F^*_{h,t} - (1 + r^*_{t-1})F^*_{h,t-1})/P_t$, which is the capital account balance in terms of consumption units. Rearranging (22) gives the Balance of Payments in Equation (23), which says the sum of current account and capital account is zero and BoP is balanced.

$$x_t + df_{h,t} = 0. \tag{23}$$

Summing up the end-period payment flows of households (15), firms (11), and the government (9), for output market clearing (22) to hold, it follows that the central bank's profit rebate to the treasury at date $t-1$ ends up paying for the interest payment on reserves at date t. Formally,

Lemma 2. *The payment flows of all agents and the output market clearing condition imply that*

$$M_t i_t = m_{t-1}. \tag{24}$$

We combine (24), (7), and (10) with the real wage equation (13) and the production function to obtain

$$\frac{m_{t-1}}{i_t}(1 + vi_t) = vP^*_t \chi_t A_t n_t. \tag{25}$$

We have also derived the Euler equation $1 + \rho^*_{t-1} = \beta^{-1}\frac{c_t}{c_{t-1}}$, and given last-period's US real interest rate ρ^*_{t-1} and last period's consumption, this period's consumption c_t is pinned down. Combining (25) and (18) leads to

$$m_{t-1} i_t^{-1} (1 + vi_t)^{1+\frac{1}{\phi}} = vP^*_t \chi_t A_t^{1+\frac{1}{\phi}} (\zeta c_t)^{-\frac{1}{\phi}}. \tag{26}$$

From (26), given last period's remittance m_{t-1} and the US price level P^*_t, with c_t already pinned down, the exchange rate peg $\chi_t = \chi$ solves for the domestic policy rate i_t uniquely in equilibrium, which means the domestic central bank cannot set its policy rate i_t for any objective other than to maintain the exchange rate peg. Without the peg, the domestic central bank can set its own monetary policy rule regarding i_t, and the nominal exchange rate χ_t is then determined by the market via (26), which may deviate from the peg. To formalize the above arguments, Proposition 1 establishes equilibrium existence and nominal determinacy of the economy, with the proof provided in Appendix C.

Proposition 1. *Let $c_t = \mathbb{P}(f_{h,t-1})$ be the policy function and $\mathbb{P}'(f_{h,t-1}) > 0$, the equilibrium is summarized by the following two equations.*

$$(1 + r^*_{t-1})^{-1}\mathbb{G}(f_{h,t-1}, i_t) = f_{h,t-1}, \tag{27}$$

where $\mathbb{G}(f_{h,t-1}, i_t) = [\mathbb{P}^{-1}(\mathbb{P}(f_{h,t-1})_t(1+\rho^*_t)\beta) + \mathbb{P}(f_{h,t-1}) - \mathbb{P}(f_{h,t-1})^{-1/\phi}A_t^{1+1/\phi}((1 + vi_t)v)^{-1/\phi}$, *and*

$$m_{t-1}i_t^{-1}(1 + vi_t)^{1+\frac{1}{\phi}} = vP^*_t\chi_t A_t^{1+\frac{1}{\phi}}(\zeta\mathbb{P}(f_{h,t-1}))^{-\frac{1}{\phi}}. \tag{28}$$

Assuming fixed remittances m_t, given the US interest rates ρ^*_t and r^*_{t-1} and the US price level P^*_t, suppose $\mathbb{P}''(f_{h,t-1}) \leq 0$, for a given domestic policy rate i_t, Equation (27) has a unique fixed point for $f_{h,t-1}$, and from (28) the exchange rate χ_t is uniquely determined; therefore, the equilibrium exists and is unique.

1. *Pegging the nominal exchange rate $\chi_t = \chi$, the domestic policy rate i_t is uniquely determined in equilibrium.*
2. *Given the domestic policy rate i_t, the nominal exchange rate χ_t is uniquely determined in equilibrium.*

In proving Proposition 1, the initial remittances m_{-1} are crucial for nominal determinacy. This is consistent with the monetary literature using cash-in-advance in general equilibrium with incomplete markets (see e.g., Dubey and Geanakoplos, 1992; Drèze and Polemarchakis, 2001; Dubey and Geanakoplos, 2003; Tsomocos, 2003; Nakajima and Polemarchakis, 2005; Dubey and Geanakoplos, 2006; Bloise and Polemarchakis, 2006). Dubey and Geanakoplos (2003) prove that for a given positive policy rate, central bank profits (or referred to as *outside money* in Dubey and Geanakoplos, 2003), however small it is, ensure a monetary general equilibrium with incomplete markets always exists and that nominal determinacy (including price level) obtains, even when its general equilibrium with incomplete markets but without money fails to exist. In an intriguing paper, Hall and Reis (2016) establish that by paying an appropriate rate on reserves (the rate paid on reserves is a cost for the central bank and would *ceteris paribus* reduce profits), the central bank can pin down the price level uniquely to a target. They show that setting the remuneration of reserves is a robust method and is free from the possibility of indeterminacy.

Proposition 1 reflects the trilemma logic: under a fixed exchange rate regime, the central bank policy rate i_t is endogenously determined in equilibrium. In contrast, when the policy rate i_t is used as a free instrument, the exchange rate is determined via the market (i.e., a floating exchange rate). Note that Proposition 1 holds when remittances are fixed, where the central bank does not actively choose the level of profits rebated to the treasury. For now, we set aside potential implementation challenges. Suppose, instead, that the central bank could choose the level of remittances – what we refer to as an active remittance policy. Could this allow the central bank to set its policy rate more freely while still upholding fixed exchange rates? We will explore this question through equilibrium analysis, followed by a discussion in Section 5 on how financial innovations, such as a central bank digital currency (CBDC), could help the central bank implement an active remittance policy.

4 Equilibrium analysis

As in Farhi and Werning (2017), we follow the tradition of Lucas Jr and Stokey (1983) by substituting out variables and constraints. Substituting (26) into the Euler equation and letting $\Delta m_t \equiv m_t/m_{t-1}$, we have

$$1 + \rho_t^* = \beta^{-1}[\frac{i_{t+1}\chi_{t+1}}{i_t\chi_t}\frac{\Pi_{t+1}^*}{\Delta m_t}]^{\phi}[\frac{(1+vi_t)A_{t+1}}{(1+vi_{t+1})A_t}]^{1+\phi}. \tag{29}$$

We can summarize this small open economy using Equation (29). Suppose the domestic central bank keeps remittances fixed so that $\Delta m_t = 1$ from $t = 0$ onwards, which we call a passive remittance policy. From (29), since the US real interest rate ρ_t^* and the US path of inflation Π_{t+1}^* are both exogenous to the domestic economy, we can see that the domestic central bank can only adjust the path of the monetary policy rate i_t, i_{t+1} to target the path of nominal exchange rates χ_t, χ_{t+1} to maintain the peg. However, if the central bank uses an active remittance policy by choosing Δm_t from $t = 0$ onwards, it has the potential to use the path of remittances to target the path of nominal exchange rates, without actively adjusting the policy rate.

4.1 Imperfect substitution between assets and money

To develop intuition as to why an active remittance policy can potentially offer flexibility in setting policy rates, for now we suppress net foreign capital flow by assuming $df_{h,t}$ is zero to solve the model in closed form. We can express labor n_t as a function of policy rate i_t as in (30) and the policy rate as a function of exchange rate, remittances and labor as in (31).

$$n_t = \Big[(1 + v i_t)\zeta\Big]^{-\frac{1}{\phi+1}}; \tag{30}$$

$$i_t = \Big(\frac{v P_t^* \chi_t A_t n_t}{m_{t-1}} - v\Big)^{-1}. \tag{31}$$

Substituting out n_t in (31) using (30), the previous two equations can be combined to give:

$$(v + \frac{1}{i_t})(1 + v i_t)^{\frac{1}{1+\phi}} = \frac{v P_t^* \chi_t A_t}{m_{t-1}} \zeta^{-\frac{1}{1+\phi}}. \tag{32}$$

It is easy to show that the left-hand side of (32) monotonically decreases with i_t. With a passive remittance policy whereby m_{t-1} is fixed and with fixed exchange rates $\chi_t = \chi$, a decrease in the US price level P_t^* thus corresponds to an increase in i_t. An increase in i_t, according to (30), decreases working capital input and thus dampens output. Nevertheless, if remittances are utilized by the central bank as a policy instrument, the impact of the decrease in P_t^* can be offset by a decrease in m_{t-1} from the last period, without needing to change i_t, and thus working capital and output remain unchanged. We characterize the equilibrium effects of the passive and active remittance policies in Lemma 3, with the proof given in Appendix B.

Lemma 3. *Suppose the net foreign capital flow $df_{h,t} = 0$ and the exchange rate is fixed $\chi_t = \chi$. Let $\Delta m_t \equiv m_t / m_{t-1}$,*

1. *With a passive remittance policy ($\Delta m_t = 1$), a decrease in the US price level leads to a decrease in domestic output, and vice versa;*
2. *With an active remittance policy (Δm_t as a policy instrument), a decrease in the US price level in the next period can be offset with a decrease in remittance in this period, without changing the domestic policy rate or output, and vice versa.*

The above lemma suggests that when the US increases its monetary policy rate to push down US inflation, the domestic policy rate has to increase under a passive remittance policy. Therefore, a passive remittance policy implies an active interest rate policy. However, under an active remittance policy, the domestic policy rate does not need to change, even though the US policy rate increases. This does not imply that the UIP for financial assets is violated, because there is imperfect substitutability between financial assets and central bank reserves. The UIP connects the inter-temporal nominal interest rates of assets, whereas the policy rate is the liquidity cost of reserves. With imperfect substitutability, the remittance policy drives a wedge between nominal interest rates of financial assets on the one hand and the monetary policy rate on the other, as Proposition 2 formalizes with the proof in Appendix D.

Proposition 2. *The change in remittances drives a wedge between the inter-temporal nominal interest rate and the monetary policy rate as in (33). This is due to imperfect substitutability between financial assets and central bank reserves. Suppose $df_{h,t} = 0$, it follows that*

$$1 + r_t = \beta^{-1} \Delta m_t \frac{v + i_{t+1}^{-1}}{v + i_t^{-1}}. \tag{33}$$

With a passive remittance policy, $\Delta m_t \equiv m_t/m_{t-1} = 1$, consider a US interest rate hike at t, which increases the domestic inter-temporal nominal interest rate r_t. According to (33), the domestic policy rate i_t has to increase, which leads to a drop in domestic output. With an active remittance policy, whereby the domestic central bank chooses Δm_t, however, the change in remittances acts as a cushion between domestic inter-temporal interest rates and the monetary policy rate, insulating the domestic economy from US interest rate hikes. This can be seen in (34), which is obtained by combining the UIP and (33):

$$1 + r_t^* = \beta^{-1} \Delta m_t \frac{v + i_{t+1}^{-1}}{v + i_t^{-1}}. \tag{34}$$

Three observations emerge. First, the inverse of this wedge reflects the liquidity premium studied in the literature on near-money assets (see, for example, Gorton, Lewellen and Metrick, 2012; Nagel, 2016). As a financial asset becomes more "money-like", the wedge decreases, which increases its liquidity premium. In this sense, our active remittance policy enables the central bank to endogenously influence the "money-ness" of financial assets to suit its policy objective. Second, Proposition 2 and Equation (34) suggest that it is the change in remittances that matters, rather than the absolute value of remittances. Even if the domestic central bank earns a very small seigniorage profit, the remittance policy is still effective if its percentage change is sufficiently large. Third, the assumption $df_{h,t} = 0$ is only used for ease of analytic exposition. Suppose we have the general case whereby net capital flow $df_{h,t} \neq 0$. In this case, Equation (33) is augmented by capital flow such that $1 + r_t = \beta^{-1} \Delta m_t (v + i_{t+1}^{-1} - \hat{df}_{h,t+1})/(v + i_t^{-1} - \hat{df}_{h,t})$, where $\hat{df}_{h,t}$ is $df_{h,t}$ normalized by m_t. This equation also demonstrates the cushioning role of Δm_t, and thus, the insight of Proposition 2 remains.

Lemma 3 and Proposition 2 have two important implications. First, the real economy is affected whenever the domestic central bank changes its policy rate. This is because the policy rate is within-period, which creates a wedge in the Euler equation – a mechanism similar in spirit to that in Niepelt (2024*b*). Second, it is possible for the domestic central bank to target the nominal exchange rate by setting the remittances endogenously rather than the policy rate, while keeping the real economic allocations unaltered. We now demonstrate that these implications carry over to more general settings. Let us assume a general production function

$y_t = f(n_t)$, and $f(n_t)$ is C^2, $f''(n) < 0 < f'(n)$, and $f(0) = 0, f''(0) = \infty$. Equation (13) becomes $f'(n_t) = w_t(1 + vi_t)$, together with (18), it follows that $1 + vi_t = \frac{1}{C_t} \frac{f'(n_t)}{\zeta n_t^{\phi}}$. Let $\mathbb{H}(y_t) \equiv \beta^{-1} f'(f^{-1}(y_t))/(\zeta(f^{-1}(y_t))^{\phi})$, then $d\mathbb{H}/dy_t < 0$. Combining the previous equation and (17), we have

$$\mathbb{H}(y_t) = (1 + vi_t)(1 + \rho_{t-1}^*)c_{t-1}. \tag{35}$$

From Equation (35), as the small open economy takes the US real interest rate as given, and given last period's consumption, an increase in the current period domestic policy rate decreases current period output, and vice versa. The changes in the domestic policy rate exert real effects. Moreover, with $y_t = f(n_t)$, Equation (21) becomes $M_t = vP_t f'(n_t)n_t/(1 + vi_t)$, which together with (24), leads to

$$vP_{t+1}^* \chi_{t+1} f'(n_{t+1})n_{t+1}i_{t+1}(1 + vi_{t+1})^{-1} = m_t. \tag{36}$$

Since n_{t+1} is a function of i_{t+1}, ρ_t^*, c_t, as can be seen in (35), we can write $f'(n_{t+1})n_{t+1} = \Psi(i_{t+1}, \rho_t^*, c_t)$, and Equation (36) can be expressed as

$$vP_{t+1}^* \chi_{t+1} \Psi(i_{t+1}, \rho_t^*, c_t)i_{t+1}(1 + vi_{t+1})^{-1} = m_t. \tag{37}$$

Equation (37) expresses the relationship between the inter-temporal US real interest rate ρ_t^* and the small open economy's intra-period monetary policy rate i_{t+1}. This represents the term structure of interest rates. As we see, remittances affect the term structure of interest rates. By setting m_t, the domestic central bank affects the future exchange rate χ_{t+1} without needing to change the policy rate i_{t+1}, so the real allocation remains unchanged. We summarize these insights in the proposition below.

Proposition 3. *Generally, given $\Delta\chi_t, c_{t-1}, r_{t-1}^*$, domestic policy rate changes are non-neutral. Remittances affect the term structure of interest rates. By setting current-period remittances endogenously, the central bank can target the future nominal exchange rate without changing the domestic policy rate.*

4.2 Transmission mechanism

To delve deeper into the transmission mechanism of passive and active remittance policies respectively, we map our equilibrium conditions into a traditional IS-LM-BP framework. We follow the approach of Goodhart, Peiris, Tsomocos and Wang (2023) to derive the IS and LM curves. We use the IS curve to show how the demand for output y_t^d changes with the domestic policy rate. We combine the households' budget flows, the government budget flows and firm profits, while substituting in

(13) and the production function to obtain

$$y_t^d = \frac{m_{t-1}}{P_t} + \frac{1}{1+vi_t} y_t^s, \tag{38}$$

where y_t^d is the demand for output and y_t^s is the firms' production plan of final goods. Given firms' production plans and domestic price level P_t, the domestic policy rate and the demand for output have an inverse relationship.

We make use of the reserve market clearing condition to obtain the micro-founded LM curve. Letting M_t^s be the supply of reserves, equating it with the transaction demand for reserves $M_t^d = vD_t$ and substituting in firms' payment flow (10) and optimality condition (13), we have

$$i_t = (\frac{vP_t y_t^d}{M_t^s} - 1)v^{-1}. \tag{39}$$

This is the locus of points in which the domestic policy rate i_t and demand for output have a positive relationship.

The balance of payment BP_t is the sum of the current account balance, or net exports x_t, and capital account balance as in (23). In line with Fleming (1962) and Mundell (1963), we assume that the current account x_t is an increasing function of nominal exchange rate χ_t and a decreasing function of y_t^d, and that the capital account $df_{h,t}$ is an increasing function of interest rate differentials between domestic assets and US dollar assets. That is,

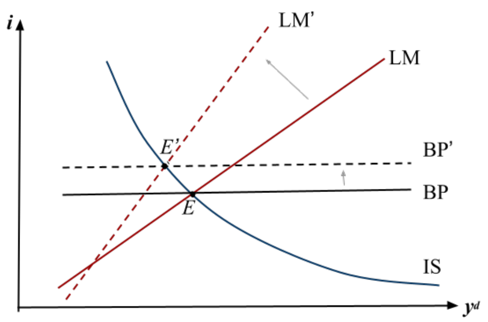
$$BP_t = x_t(\underset{+}{\chi_t}, \underset{-}{y_t^d}) + df_{h,t}(r_t \underset{+}{-} r_t^*). \tag{40}$$

Suppose for a moment there is imperfect capital mobility. When the domestic central bank decreases the monetary policy rate i_t, which pushes down the nominal interest rate r_t of domestic assets, the capital account moves into deficit $df_{h,t} < 0$, and for BoP to balance, the demand for output y_t^d must decrease to generate a current account surplus. This produces an upward-sloping BP curve with r_t on the vertical axis and y_t^d on the horizontal axis. Assuming perfect capital mobility, the BP curve becomes a horizontal line. Furthermore, as we have shown in Proposition (2) that the domestic asset return r_t is a function of the domestic policy rate and the remittance change, we can write (40) as $BP_t = x_t(\chi_t, y_t^d) + df_{h,t}(r_t(i_t, \Delta m_t) - r_t^*)$, which connects BP to the domestic policy rate i_t. This is illustrated by the BP lines in Figure 3 with the policy rate i_t being on the vertical axis and y_t^d on the horizontal axis. Whenever the domestic central bank raises the policy rate, the BP curve shifts upwards, as $BP \rightarrow BP'$ in Figure 3a.

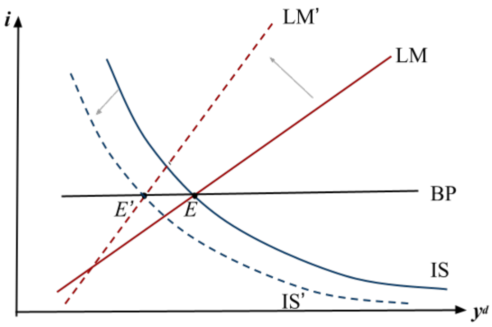
Note that along the IS curve the labor market clears but not necessarily the reserve market, while along the LM curve the reserve market clears but not necessarily the labor market. The BP curve is where the BoP is in balance. The intersection of IS, LM and BP gives us the locus of points for the demand for output as a function of the policy rate where both the labor market and the reserve market clear and the BoP is balanced, for a given price level.

Figure 3 puts together the IS-LM-BP. Consider a monetary tightening in the US which reduces US inflation, i.e., P_t^* is to go down given P_{t-1}^*. To keep the exchange rate $\chi_t = P_t/P_t^*$ pegged to the target, the domestic central bank must lower P_t. To this end, the domestic central bank can use either a passive remittance policy which implies an active interest rate policy, or an active remittance policy while keeping the policy rate unchanged. The left panel Figure 3a illustrates a passive remittance policy and the right panel Figure 3b illustrates an active remittance policy with which the domestic central bank aims to lower P_t.

Figure 3: Mapping into IS-LM-BP



(a) Passive remittance policy



(b) Active remittance policy

Figure 3a illustrates a passive remittance policy. The domestic central bank tightens reserve supply M_t^s to increase the policy rate but does not change remittances. This action steepens the LM curve and moves it to the left ($LM \rightarrow LM'$), causing the policy rate to increase. The increase in the policy rate shifts the BP curve upwards and meanwhile dampens the demand for output through the IS curve. The change in the policy rate does not move the IS curve. To sum up, the original locus point E moves to E' which corresponds to a higher policy rate and lower demand for output.

Figure 3b illustrates an active remittance policy. The domestic central bank reduces the profit rebate of the last period m_{t-1} to the treasury account, and according to Lemma 2, this action tightens the central bank's endogenous reserve supply. This steepens the LM curve and moves it to the left, exerting upward pressure on the policy rate. In contrast to a passive remittance policy, whereby the IS curve remains unchanged, this action under the active remittance policy also reduces the demand for output and shifts the IS curve downwards, as can be seen in Equation (38). This exerts downward pressure on the policy rate. The upward pressure and downward pressure offset each other, leaving the policy rate unchanged, and hence, the BP line stays the same, but the demand for output goes down (as in $E \to E'$ in Figure 3b).

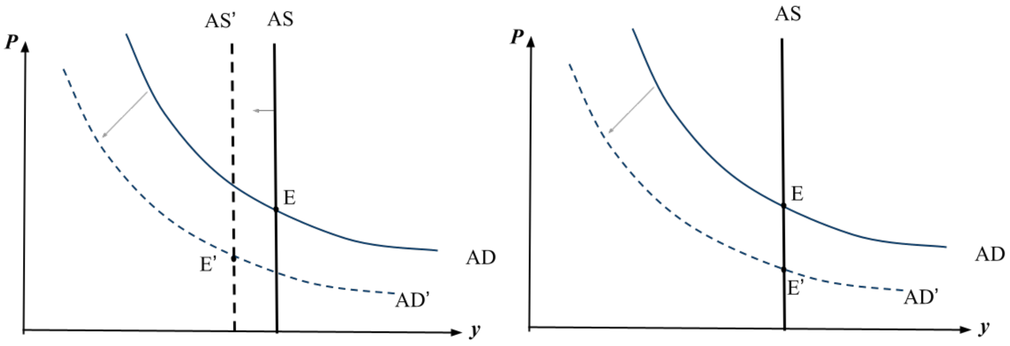
In sum, with a passive remittance policy, monetary tightening increases the policy rate and reduces the demand for output; under an active remittance policy, reducing the profit rebate to the treasury reduces the demand for output without changing the policy rate. What do these differences imply for the domestic price level? Recall that in this experiment, the domestic central bank aims to the lower domestic price level to maintain the nominal exchange rate peg due to US monetary tightening. Since the IS-LM-BP focuses on the aggregate demand for output, we need to clear the output market by bringing in aggregate supply and equating it with aggregate demand to see how the price level changes. The aggregate demand (AD) curve can be expressed as (38) with the domestic price level on the vertical axis and output on the horizontal axis. To derive the aggregate supply (AS) curve, we combine the firm's optimality condition (13), the labor supply curve (18), and the production function $y_t = A_t n_t$ to derive the supply of output (firms' production plans) y^s implied by the following equation

$$\zeta \left(y_t^s\right)^{\phi} c_t = \frac{A_t^{1+\phi}}{1 + v i_t}. \tag{41}$$

Since in a small open economy current consumption c_t is pinned down by the last period's consumption and the US real interest rate ρ_{t-1}^* via (20), according to (41) the aggregate supply of output has an inverse relationship with domestic policy rate i_t. An increase in i_t moves the AS curve to the left. We summarize the AS-AD framework in Figure 4 below. The left panel illustrates a passive remittance policy and right panel illustrates an active policy.

As a passive remittance policy reduces aggregate demand and also increases the policy rate, both the AS and AD curves move to the left. This action lowers the price level, as intended by the domestic central bank, but it also lowers output produced in equilibrium. This is illustrated in Figure 4a. Since an active remittance policy reduces aggregate demand but does not move the policy rate, the AS curve in this case stays the same but the AD curve moves to the left. This action lowers the price level, as desired by the central bank, but the output remains unchanged. This is illustrated in Figure 4b. Therefore, an active remittance policy can act as a cushion and shield domestic production from US monetary tightening.

Figure 4: Price Level and Output in AS-AD



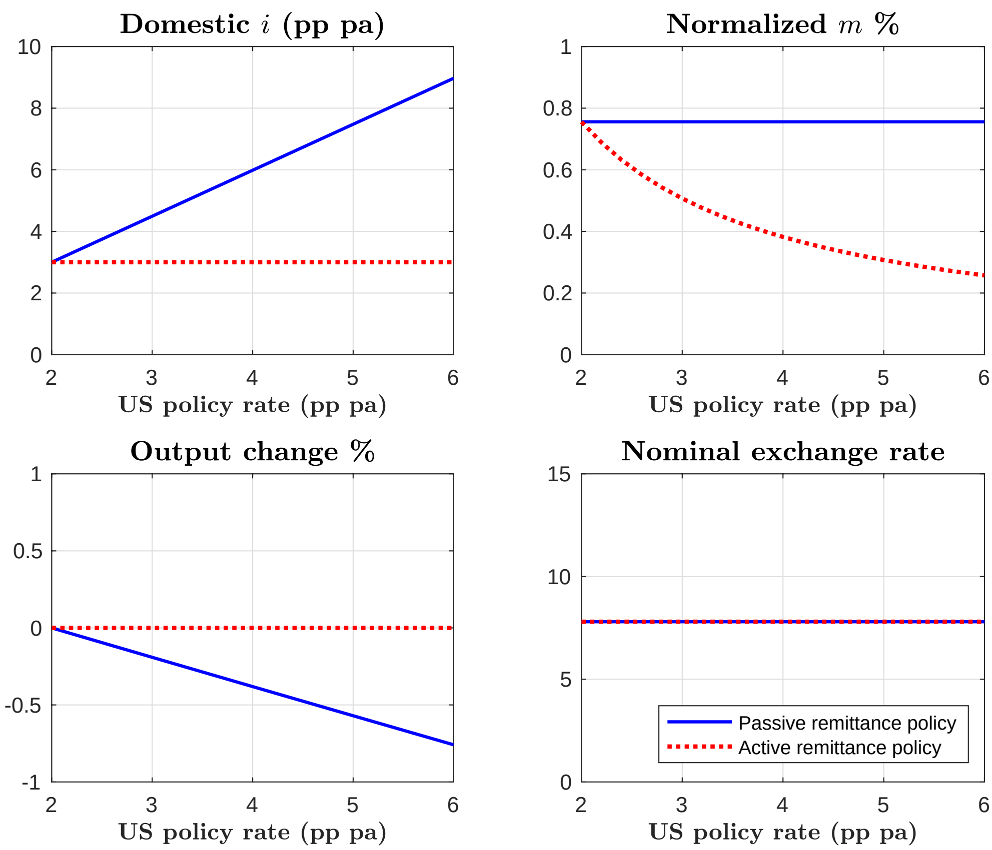
(a) Passive remittance policy (b) Active remittance policy

4.3 Numerical examples

To elucidate the transmission mechanism, we solve the full model numerically and demonstrate that the different transmission mechanisms of passive and active remittance policies also hold in the steady state. The base values of the model parameters used in the numerical examples are provided in Table 4 of Appendix F. Below the table, we describe how these values are chosen or calibrated. We use the Hong Kong data to calibrate the steady state level of central bank equity and the investments in US assets. To calibrate the steady state central bank equity, we use a Hong Kong policy rate of 3% per annum and an exchange rate against the US dollar as 7.8 HKD/USD. The Hong Kong policy rate averaged around 3% per annum from 1992 to 2023, and the nominal exchange rate is pegged to the US dollar at 7.8 with fluctuations within a band. To calibrate the strength of monetary policy rate passthrough to loan rates, we use the correlation between the quarterly Hong Kong Interbank Offered Rate (HIBOR) and Hong Kong banks' net interest margin from 2005 to 2023, which is 0.67, and it is sufficiently close to the correlation between HIBOR and banks' Best Lending Rate, which is 0.74. For robustness checks we also vary the policy rate and the pegged exchange rate. We obtain the steady state level of US asset positions using Hong Kong's BoP data. From 2010 to 2023, the highest quarterly current account balance-to-GDP ratio is 16.3%; therefore, we set the absolute value of the quarterly current account balance-to-GDP ratio to be 20% to calibrate the maximum of capital flow magnitude through the capital account, and we obtain $[-1.42, 1.42]$ as the range of the steady state US asset positions in terms of domestic consumption units for our sensitivity analysis.

We first show how the steady state equilibrium responds to US policy rate changes. We solve for the case of a passive remittance policy, illustrated by the blue solid lines in Figure 5, and the case of an active remittance policy, illustrated by the red dashed lines in Figure 5. In the passive remittance case, as the US policy rate increases from 2% to 6% per annum, the domestic policy rate must increase in lockstep from 3% to 9% (top left panel), in order to maintain the exchange rate peg (bottom right panel); nevertheless, the steady state remittances remain the same (top right panel). Due to the rise of the policy rate, the borrowing cost of private agents rises in the steady state, and hence, we see that quarterly output decreases by 0.76% in the steady state (bottom left panel).

Figure 5: **Sensitivity of steady state to the US policy rates**



This figure simulates the domestic economy's steady state equilibrium while increasing the US policy rate from 2% to 6% per annum. The blue solid lines correspond to the passive remittance policy, and the red dashed lines correspond to the active remittance policy. The top left panel displays the domestic policy rate (pp per annum), the top right panel displays remittances normalized by the base case central bank equity, the bottom left panel displays quarterly output percentage changes relative to the base case output, and the bottom right panel displays nominal exchange rates.

Under an active remittance policy, the steady state equilibrium responses are drastically different. As the US raises the policy rate, the domestic policy rate can be left unchanged (top left panel of Figure 5), but the level of remittances has to be actively reduced (top right panel). The decrease in the profit rebates to the treasury is able to maintain the exchange rate peg (bottom right panel). Since the policy rate remains unchanged, the borrowing costs of private agents do not change, and output does not deteriorate (bottom left panel). This is despite the US rate hikes and fixed exchange rates. Notably, the reduction in remittances-to-nominal GDP ratio needed to uphold the exchange rate peg only amounts to 0.16%. This is equivalent to 0.11%

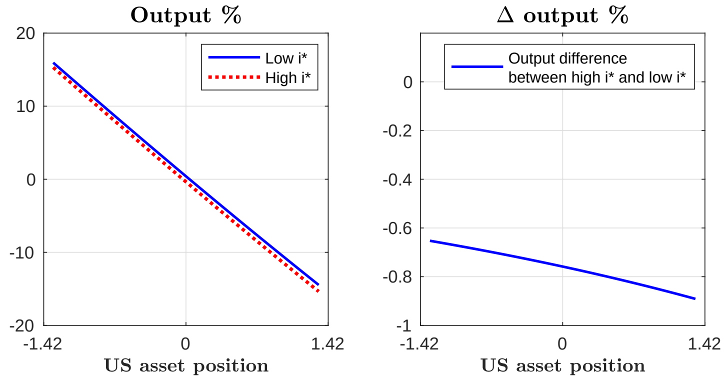
of central bank assets, which is obtained by noting that the average central bank total asset-to-GDP ratio in Hong Kong for the period 2011-2022 is 1.53. Since the average ROA (Hong Kong central bank total income/its total assets) over the same period is 0.46%, the required remittance produced by our model is well within the boundaries implied from the central bank income.

We conduct sensitivity analysis with respect to the steady state US asset position. We vary the steady state US asset position from -1.42 to 1.42, which is an extremely large range.[9] A negative figure corresponds to a capital account deficit and current account surplus in the steady state, and vice versa. Figure 6 illustrates the steady state solution in response to US asset positions in the passive remittance case, and Figure 7 illustrates that of the active remittance case. The blue lines correspond to a low US policy rate scenario (2% per annum) and the red dashed lines correspond to a high US policy rate scenario (6% per annum). As the US asset position increases, output in all scenarios fall (left panels of Figures 6 and 7), because the increase of the wealth effect from asset portfolios reduces households' marginal incentive to supply labor for production.

There are two noticeable differences between the passive remittance case and the active one. In the passive remittance case, there is a gap between output levels: the output in the steady state is always lower when facing a high US policy rate than when facing a low US policy rate (middle panel of Figures 6). In the active case, there is no such gap (middle panel of Figures 7). This is because in the passive case, a higher US policy rate forces the domestic policy rate to go up, which hurts production, whereas in the active case the domestic policy rate is unchanged, which means the output facing a higher US policy rate is the same as that facing a lower US policy rate. Interestingly, in the passive remittance case, the gap between output levels increases in magnitude as the US asset position increases (middle panel of Figures 6). This is because the domestic policy rate is more sensitive when the US asset position is high. In the active remittance case, remittance is always lower in the high US rate scenario than in the low US rate scenario (right panel of Figure 7), in order to maintain the peg. As the US asset position increases causing depreciation pressure on the domestic currency, remittances need to be reduced to maintain the exchange rate peg.

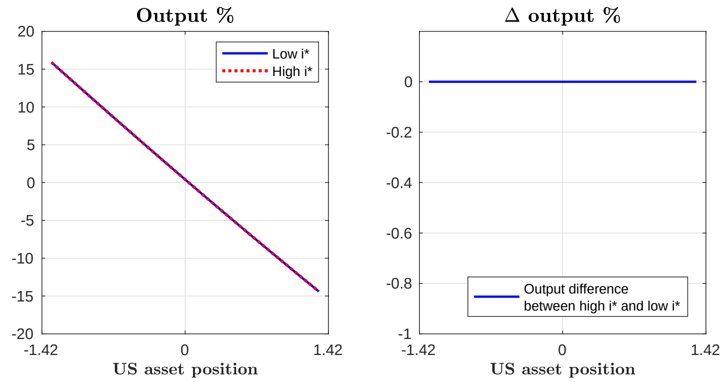
[9] It is a large range because 1) this is a steady state number, which means the capital account balance only results from interest payments, and 2) it is set by benchmarking Hong Kong's largest capital account/current account balance in the past 13 years.

Figure 6: **Sensitivity of steady state to US assets with passive remittances**



This figure simulates the domestic economy's steady state equilibrium while varying the steady state US asset position from -1.42 to 1.42 under the passive remittance policy. The blue solid lines correspond to a low US rate scenario of 2% per annum and the red dashed lines correspond to a high US rate scenario of 6% per annum. The left panel displays output changes relative to the base case steady state output, the middle panel displays the gap between the output level facing a high US rate and that facing a low US rate, normalized by the base case steady state output. The right panel displays domestic policy rate responses.

Figure 7: **Sensitivity of steady state to US assets with active remittances**



This figure simulates the domestic economy's steady state equilibrium while varying the steady state US asset position from -1.42 to 1.42 under the active remittance policy. The blue solid lines correspond to a low US rate scenario of 2% per annum and the red dashed lines correspond to a high US rate scenario of 6% per annum. The left panel displays output changes relative to the base case steady state output, the middle panel displays the gap between the output level facing a high US rate and that facing a low US rate, normalized by the base case steady state output. The right panel displays active remittance responses normalized by the base case central bank equity.

4.4 Balance sheet constraints

So far, our analysis has implicitly assumed that under an active remittance policy, the remittance change $dm_t = m_t - m_{t-1}$ is small enough to not violate the central bank balance sheet constraint, i.e., $E_t > 0$ is always satisfied. Through the law of motion for central bank equity, however, if the current-period remittance to the treasury is sufficiently large, it can lead to negative equity in the next period. Let $\xi_t \equiv \chi_t(F_t^*(1+r_t^*) - F_{t+1}^*) - (\epsilon_t(1+r_t) - \epsilon_{t+1})$, which is the financial wedge between US assets and central bank notes. Combining (5) and (24), we obtain Equation (42), which says the central bank's current-period seigniorage profits consist of the financial wedge ξ_t and its remittances m_{t-1} of the last period, net of all other expenses. The reason why the central bank's remittances in the last period constitute this period's seigniorage profits is that the remittances in the last period end up paying the interest payment on reserves in the current period through the flow of funds and market clearing for reserves and output, as we have shown in Lemma 2.

$$S_t = m_{t-1} + \xi_t - z_t. \tag{42}$$

Substituting (42) into the law of motion for central bank equity (6), we have $E_{t+1} = E_t + \xi_t - z_t - dm_t$. Apparently, for $E_{t+1} > 0$ to hold, $dm_t < E_t + \xi_t - z_t$ needs to be satisfied.

Must central banks hold positive equity? In practice, the Fed has had negative equity by creating the deferred asset entry. For central banks operating under an exchange rate peg, we show that negative equity is not possible using proof by contradiction. Note that the balance sheet accounting (3) can be written as $\chi_t F_t^* - \epsilon_t = E_t$ because $M_t = \mu_t$. Suppose $E_t < 0$, then $\chi_t F_t^* < \epsilon_t$. However, given $\chi_t = \chi$ and the UIP, the dollar-backing condition (4) leads to $\chi_t F_t^* > \epsilon_t$. This is a contradiction. We summarize this result in the proposition below.

Proposition 4. *Central banks operating under a nominal exchange rate peg cannot hold negative equity. Under the active remittance policy, there exists an upper bound for the change of remittances, namely,* $dm_t < E_t + \xi_t - z_t$.

Proposition 4 highlights a balance sheet constraint for the active remittance policy. Another balance sheet constraint results from the fact that the dollar-backing condition (4) has to be satisfied at all times. We posit that a sufficiently large change in remittances can induce the dollar-backing condition to be binding, i.e. $\eta_t > 0$. Suppose the domestic central bank increases remittance m_t this period, then the central bank's next period equity E_{t+1} has to decrease. From (3) and (4), this decreases the interest payment spread between the US assets and central bank notes at $t+1$, which tightens the dollar-backing condition (4). We denote e_t as the threshold whereby whenever $dm_t/E_t > e_t$, the shadow price of the dollar-backing condition (4) is positive. Proposition 5 formalizes this result, with the proof in Appendix E.

Proposition 5. *In equilibrium,*

1. *When* $\frac{dm_t}{E_t} \leq e_t$, *the active remittance policy is unconstrained.*

2. *When* $e_t < \frac{dm_t}{E_t} \leq 1 + \frac{\xi_t - z_t}{E_t}$*, the active remittance policy exerts real effects. The domestic central bank cannot use the remittance policy to target exchange rates while keeping domestic production insulated.*

3. *When* $1 + \frac{\xi_t - z_t}{E_t} \leq \frac{dm_t}{E_t}$*, the exchange rate peg is violated.*

When the change in remittances is sufficiently small relative to central bank equity ($\frac{dm_t}{E_t} \leq e_t$), or on the flip side, when the central bank equity is sufficiently large, the domestic central bank can set the current period remittances endogenously to target the future nominal exchange rates, without replying on the domestic policy rate, as in Proposition 3. Therefore, the domestic economy is insulated from US interest rate shocks. However, when the central bank equity is inadequate, or the required change in remittances is too large relative to equity, the domestic economy is distorted via the positive shadow price of the binding dollar-backing condition. Therefore, changing remittances leads to changes in the shadow price and in turn changes in real allocations. To see how the real economy is affected by the active remittance policy through its impact on the shadow price of the binding dollar-backing condition, we note that whenever $\eta_t > 0$, the firm optimality condition becomes $w_t = A_t/(1 + vi_t + \eta_t)$ instead of (13). This means we can write real allocations as a function of domestic interest rate, the shadow price, and the US real interest rate as below (see the derivations in Appendix E).

$$A_t(\zeta \beta n_t^{\phi} c_{t-1})^{-1} = (1 + vi_t + \eta_t)(1 + \rho^*_{t-1}). \tag{43}$$

Thus, given last period's consumption and the US real interest rate, an increase in η_t decreases this period's production input and hence output. Suppose $e_t < \frac{dm_t}{E_t} \leq 1 + \frac{\xi_t - z_t}{E_t}$, an increase in this period's remittances m_t exerts downward pressure on the central bank equity E_{t+1}, which tightens the dollar-backing condition. The increase in η_t dampens output; see Eq (43). When the central bank chooses to decrease remittances, however, the shadow price goes down, leading to a boost in domestic production. In either case, the change in remittances affects the real economy, in contrast to our benchmark model where we assume the dollar-backing condition is not binding. As summarized in Proposition 5, whether the active remittance policy can succeed in maintaining the exchange rate peg without affecting the real economy crucially depends on the adequacy of the equity position of the domestic central bank.

5 Implementation with a CBDC

An active remittance policy implies that the central bank actively decides the timing and size of profit rebates to the treasury, which may be challenging to implement in practice. However, with advancements in financial technology, the central bank could resort to alternative means to indirectly influence the profit rebates to the treasury without directly choosing remittances. One way to implement this is via a central bank digital currency (CBDC).

The literature on CBDCs is fast-growing (see, e.g., Brunnermeier and Niepelt, 2019; Andolfatto, 2021; Auer, Frost, Gambacorta, Monnet, Rice and Shin, 2022; Barrdear and Kumhof, 2022; Whited, Wu and Xiao, 2022; Chiu and Davoodalhosseini, 2023; Niepelt, 2024*a*; Schilling, Fernández-Villaverde and Uhlig, 2024, non-exhaustive). Existing literature offers various rationales and micro-foundations for the benefits of CBDCs. These rationales include the privacy CBDCs can provide to users (Garratt and Van Oordt, 2021; Ahnert, Hoffmann and Monnet, 2022), the ability to recover personal loss (Kahn, Van Oordt and Zhu, 2021), and security features of CBDCs (Kahn, Rivadeneyra and Wong, 2020). For our purposes, we only need to assume that households derive an additional convenience benefit of CBDC relative to demand deposits, without taking a specific stance on its underlying rationales. In our setup, a CBDC is a central bank liability held directly by households. It is a different central bank liability than reserves because the former is held by the households and the latter can only be held by commercial banks.

Households derive a convenience benefit from holding a CBDC which is equivalent to ι in real value per unit of a CBDC. The domestic central bank provides a fixed quantity of CBDCs (q^c) to households and it chooses a fee κ_t each period. We assume that $\kappa_t < min(m_{t-1}, \iota q^c))$, so the fee is conditional on the convenience benefit. The fee is smaller than ιq^c such that households strictly prefer CBDCs to demand deposits. It is smaller than m_{t-1} in order for both the output market and reserve market to clear. The fee chosen by the central bank can also be negative, in which case the fee is a subsidy. When households convert q^c units of demand deposits to CBDCs, the commercial banks must borrow from the central bank to obtain q^c units of reserves at the cost of i_t. This ensures that the central bank does not directly distribute CBDCs to private agents, but rather CBDCs are distributed via the payment system. As in our benchmark model, the central bank's balance sheet is not directly exposed to firm borrowing. Furthermore, we rule out the central bank choosing remittances m_t in this section, so m_t is fixed to m_{-1}.

As before, households get demand deposits D_t as wage payments $D_t = W_t n_t$. They convert q^c units of demand deposits on par to CBDCs, so the remaining demand deposit balance becomes $D'_t = D_t - q^c$. Households' sequential budget flow becomes

$$P_t c_t + B_t + \chi_t F^*_{h,t} + T_t = (1 + r_{t-1})B_{t-1} + \chi_t(1 + r^*_{t-1})F^*_{h,t-1} + D'_t + (q^c - \kappa_t) + \Omega_t. \tag{44}$$

A snapshot of the central bank balance sheet is modified to Figure 8.

Figure 8: Stylised Central Bank Balance Sheet with CBDCs

χF^*: US dollar assets	ϵ: central bank notes
μ: loans to domestic commercial banks	M': domestic reserves q^c: CBDCs
	E: Equity

Repeating the same steps that lead to Equation (24) in Lemma 2, we now have

$$M_t i_t = m_{t-1} - \kappa_t. \tag{45}$$

Repeating the same steps that lead to Equation (32) while incorporating (45), we now have

$$(v + \frac{1}{i_t})(1 + vi_t)^{\frac{1}{1+\phi}} = \frac{vP_t^* \chi_t A_t}{m_{-1} - \kappa_t} \zeta^{-\frac{1}{1+\phi}}. \tag{46}$$

As can be seen in (46), with CBDCs the central bank can set the fee κ_t to offset the changes in the US price level P_t^*, without needing to change its domestic policy rate, as long as $\kappa_t < min(m_{-1}, \iota q^c)$ holds. The upper bound of κ_t also reflects the limitation of setting the fees on holding CBDCs: if the convenience benefit of CBDCs is too small or initial remittances are too low relative to the shock stemming from the US, κ_t will hit its limit. Beyond this limit the domestic central bank can no longer use CBDCs to implement its "active remittance policy" through the backdoor. Proposition 6 summarizes the results in this section.

Proposition 6. *If the central bank cannot directly set its remittances to the treasury, it can choose the fees κ_t of CBDCs to target the nominal exchange rate without changing the policy rate, as long as $\kappa_t < min(m_{-1}, \iota q^c)$ holds. A decrease (an increase) in the US price level can be offset by an increase (a decrease) in the fee contemporaneously. A low convenience benefit of CBDCs or low central bank profits limit the efficacy of setting the fee.*

6 Conclusion

The conventional wisdom of the international trilemma suggests that central banks with exchange rate pegs and free capital flows lack the autonomy to set the monetary policy rate. While maintaining UIP for financial assets, we show that this constraint on setting the policy rate is not absolute when financial assets and central bank reserves are not perfectly substitutable. As a result of imperfect substitutability, the central bank's profit rebate to the treasury drives a wedge between the nominal interest rates on financial assets and the policy rate, which is the liquidity cost of reserves. By setting the profit rebate endogenously to establish the wedge as a buffer, the central bank can counteract the effect of US policy rate shocks.

Motivated by the empirical evidence that central bank profits matter for inflation and exchange rates, we build a small open economy model with a dollar peg, while carefully tracking the central bank's profit rebate to the treasury. Key ingredients of the model include the central bank balance sheet and payment systems. Our analysis illustrates how to set an active remittance policy, which uses the profit rebate as an additional policy instrument, to generate flexibility for the central bank's policy rate setting and break the trilemma. We characterize the economic allocations and prices with both a passive and an active remittance policy. Moreover, we uncover how the adequacy of the central bank equity position can affect the effectiveness of an active remittance policy. Finally, we show how a CBDC can help to implement an active remittance policy.

Although we model an exchange rate peg, our mechanism is relevant for emerging market economies more generally, since empirically many emerging market economies display patterns consistent with foreign exchange interventions for exchange rate stabilization. Our model puts the financing role of money at the center stage and utilizes the nexus between the central bank and the treasury to enrich the central bank's toolbox. It underscores the importance of a central bank's balance sheet and profit rebates in understanding the monetary transmission mechanism. Future work includes exploring our mechanism in the presence of sovereign risks (Du and Schreger, 2022) and the "dilemma issue" in global financial cycles (Rey, 2015).

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Appendices

A Proof of Lemma 1

Commercial banks maximize their real profits ω_t^b valued by households' marginal utility λ_t

$$\lambda_t \omega_t^b,$$

by choosing L_t, D_t, M_t, μ_t, subject to

$$P_t \omega_t^b = L_t(1 + i_t^l) - D_t + M_t - \mu_t(1 + i_t). \tag{47}$$

Substituting the equation for demand deposits creation via loans $L_t = D_t$, as well as Equations (2) and (7) into (47) by replacing L_t, M_t, μ_t as functions of D_t, we find that banks' decision boils down to choosing D_t. The first-order condition leads to $i_t^l = v i_t$. □

B Proof of Lemma 3

Suppose $df_{h,t} = 0$, $y_t = c_t$, we have solved labor as

$$n_t = \Big[(1 + v i_t)\zeta_t\Big]^{-\frac{1}{\phi+1}}. \tag{48}$$

Combine (48), (21), and (24), and assume a passive remittance policy $m_t = m_{-1}$, we have

$$m_{-1}(\frac{1}{i_t} + v) = v\chi_t P_t^* A_t[(1 + v i_t)\zeta_t]^{-(1+\phi)^{-1}}. \tag{49}$$

Total differentiation of the above equation gives $(-i_t^{-2} m_{-1} - v\chi_t A_t P_t^*(1+\phi)^{-1}[(1+ v i_t)\zeta_t)^{-(1+\phi)^{-1}-1}\zeta_t]di_t = v\chi_t A_t[(1 + v i_t)\zeta_t]^{-(1+\phi)^{-1}} dP_t^*$. It follows that $\frac{di_t}{dP_t^*} < 0$. This means that a decrease in the US price level increases i_t, which, according to (48), decreases n_t and, in turn, y_t.

Under an active remittance policy, the central bank sets m_t every period, with (48) we can rewrite (49) as

$$i_{t+1} = (\frac{v P_{t+1}^* \chi y_{t+1}}{m_t} - v)^{-1}. \tag{50}$$

From the above equation, under perfect foresight, when the domestic central bank central bank at t expects the US price level to fall at $t+1$, it can decrease the remittance m_t at t, without changing i_{t+1}, and thus, y_{t+1} remains unchanged.

□

C Proof of Proposition 1

The real resource constraint is $c_t + f_{h,t} - (1+r^*_{t-1})f_{h,t-1} = A_t n_t$, which is equivalent to

$$f_{h,t} + c_t - A_t^{1+1/\phi}((1+vi_t)v)^{-1/\phi}c_t^{-1/\phi} = (1+r^*_{t-1})f_{h,t-1}. \tag{51}$$

We have derived the Euler equation

$$c_t(1+\rho^*_t) = \beta^{-1}c_{t+1}. \tag{52}$$

Suppose the policy function for consumption $c_t = \mathbb{P}(f_{h,t-1})$, and $\mathbb{P}'(f_{h,t-1}) > 0$, then (52) can be written as $\mathbb{P}(f_{h,t-1})_t(1+\rho^*_t) = \beta^{-1}\mathbb{P}(f_{h,t})$, which is equivalent to

$$f_{h,t} = \mathbb{P}^{-1}(\mathbb{P}(f_{h,t-1})_t(1+\rho^*_t)\beta). \tag{53}$$

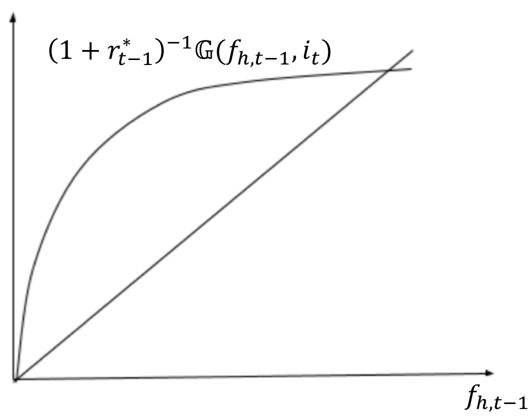
Substitute the policy function and (53) into (51):

$$(1+r^*_{t-1})^{-1}\Big[\mathbb{P}^{-1}(\mathbb{P}(f_{h,t-1})_t(1+\rho^*_t)\beta)+\mathbb{P}(f_{h,t-1})-\mathbb{P}(f_{h,t-1})^{-1/\phi}A_t^{1+1/\phi}((1+vi_t)v)^{-1/\phi}\Big] = f_{h,t-1}. \tag{54}$$

Note that US interest rates r^*_{t-1}, ρ^*_t are exogenous to the open economy, and for a given domestic policy rate i_t, the above equation can be written as

$$(1+r^*_{t-1})^{-1}\mathbb{G}(f_{h,t-1}, i_t) = f_{h,t-1}, \tag{55}$$

where $\mathbb{G}(f_{h,t-1}, i_t) = [\mathbb{P}^{-1}(\mathbb{P}(f_{h,t-1})_t(1+\rho^*_t)\beta) + \mathbb{P}(f_{h,t-1}) - \mathbb{P}(f_{h,t-1})^{-1/\phi}A_t^{1+1/\phi}((1+vi_t)v)^{-1/\phi}$. We can see that $\lim_{f_{h,t-1}\to 0}\mathbb{G}(f_{h,t-1}, i_t) \to \infty$. And $\mathbb{P}'(f_{h,t-1}) > 0$ implies that $\mathbb{G}'(f_{h,t-1}, i_t) > 0$. Moreover, if $\mathbb{P}''(f_{h,t-1}) \le 0$, for a given i_t, we have $\mathbb{G}''(f_{h,t-1}, i_t) < 0$. Therefore, Equation (55) has a unique fixed point.



Furthermore, substitute the policy function into (26), we have

$$m_{t-1} i_t^{-1} (1 + v i_t)^{1+\frac{1}{\phi}} = v P_t^* \chi_t A_t^{1+\frac{1}{\phi}} (\zeta \mathbb{P}(f_{h,t-1}))^{-\frac{1}{\phi}},$$

which says, for a given i_t, the exchange rate χ_t is uniquely determined, since we have established the unique fixed point for $f_{h,t-1}$ for a given i_t. And if χ_t is fixed, then i_t is uniquely determined in equilibrium.

□

D Proof of Proposition 2

Assuming $\Delta_{h,t} = 0$, it follows that $A_t n_t = c_t$, and we combine (16) and (21) to obtain $1 + r_t = \beta^{-1} \frac{M_{t+1}(1+vi_{t+1})}{M_t(1+vi_t)}$. Given (24) holds when the output market and money market both clear, it follows that $1 + r_t = \beta^{-1} \Delta m_t \frac{v+i_{t+1}^{-1}}{v+i_t^{-1}}$.

□

E Proof of Proposition 5

Given $\chi_t = \chi$, combining $M_t = \mu_t$, (19), (3), and (4) gives

$$M_t \leq E_t(1 + r_t). \tag{56}$$

Let η_t be the shadow price of (56). When $\eta_t = 0$, $M_t \leq E_t(1+r_t)$ is non-binding, and when $\eta_t > 0$, $M_t \leq E_t(1 + r_t)$ is binding. Given (6), an increase in m_t reduces E_t, and so when dm_t/E_t is sufficiently large ($dm_t/E_t > e_t$), $\eta_t > 0$.

When $\eta_t > 0$, the firm optimality condition becomes $w_t = \frac{A_t}{1+vi_t+\eta_t}$. Combine the previous equation with (18), we have $c_t(1 + vi_t + \eta_t) = \frac{A_t}{\zeta n_t^{\phi}}$. Substituting the previous equation into Euler equation (17), it follows

$$\frac{A_t}{\zeta \beta n_t^{\phi}} = (1 + vi_t + \eta_t)(1 + \rho_{t-1}^*) c_{t-1}. \tag{57}$$

Given c_{t-1} and ρ_{t-1}^*, an increase in η_t decreases this period's n_t and output y_t. An increase (decrease) in remittance m_t this period decreases (increases) E_{t+1}, which increases (decreases) η_{t+1}, pushing down (up) future output y_{t+1}.

When $\frac{dm_t}{E_t} < e_t$, the remittance policy is unconstrained. When $e_t < \frac{dm_t}{E_t} < 1 + \frac{\xi_t - z_t}{E_t}$, the remittance policy exerts real effects. The domestic central bank cannot use the remittance policy to target the exchange rate while keeping the domestic economy insulated.

□

F Parameterization

Parameter	Description	Base case	Target or Range
β	Discount factor	0.9925	Quarterly
ζ	Labor disutility parameter	3.08	
ϕ	Inverse of Frisch elasticity	0.3	
v	Pass-through parameter	0.67	
B	Steady state government debt	0	$[-0.5, 0.5]$
$\chi F_h^*/P$	Steady state investment in US assets	0	$[-1.42, 1.42]$
E/P	Steady state central bank equity	0.41	$\chi = 7.8; i = 3\%$
A	Productivity	1	
P^*	US price level	1	

Table 4: This table shows the base values of the exogenous model parameters for our numerical examples. The last column shows the calibration target or the range of values considered in the sensitivity analysis. The steady state US asset position F_h^* is expressed in terms of domestic consumption units, i.e., $\chi F_h^*/P$. The steady state central bank equity is expressed in real value.

Comments on the simulation:

- We take the discount factor as 0.9925 to calibrate the real interest rate at quarterly frequency. The labor disutility parameter ζ is taken as 3.08, following Bhattarai, Lee and Yang (2023).

- We take the inverse of the Frisch elasticity ϕ to be 0.3, following Gertler and Karadi (2011).

- We use the Hong Kong policy rate 3% pa and exchange rate $\chi = 7.8$ to calibrate the steady state level of central bank equity. The Hong Kong policy rate averaged around 3% pa from 1992 to 2023, and the nominal exchange rate is pegged to the US dollar at 7.8 with fluctuations within a band. We vary the policy rate and the pegged exchange rate for robustness checks.

- The pass-through parameter v is calibrated as 0.67 by using the correlation between Hong Kong banks' net interest margin and the Hong Kong Interbank Offered Rate over the last 20 years, and cross-checked using the correlation between Hong Kong banks' Best Lending Rate and HIBOR. Our calibrated value is close to the US counterpart of 0.78 (excluding the US Zero Lower Bound episode) in Goodhart, Tsomocos and Wang (2023).

- For our benchmark case, we take the steady state level of government debt and household investment in the US dollar assets to be zero. For sensitivity analysis, we choose the range $[-1.42, 1.42]$ for the steady state level of investments in US assets in terms of domestic consumption units. This is obtained through BoP and the current account balance-to-GDP ratio. From 2010 to 2023, the highest quarterly current account balance-to-GDP ratio is 16.3%; therefore, we set the absolute value of the quarterly current account balance-to-GDP ratio to be 20% to calibrate the maximum capital outflow through the capital account, and we obtain $[-1.42, 1.42]$ for range of the steady state level of US asset positions. We choose the range [-0.5, 0.5] for government debt for robustness checks.

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G Extension

In this extension, we allow commercial banks to hold both inter-temporal and intra-period financial assets. The intra-period assets can be sold at any point within periods to the central bank to obtain reserves for short-term liquidity needs. The inter-temporal assets include a portfolio of domestic assets $B_{b,t}$ and US dollar assets $F^*_{b,t}$. Commercial banks use inter-temporal interest-bearing time deposits $\bar{D}_t$ to fund their investments in inter-temporal financial assets. The intra-period assets with face value η_t are sold to the central bank at a discounted price $q_t\eta_t$ to obtain reserves and $q_t = 1/1 + i_t$, and at the end of the period η_t must be redeemed. Let $\lambda_t = \frac{1}{c_t}$ be households' marginal utility, and the stochastic discount factor for date s $(s \geq t)$ is $\beta^{s-t}\frac{\lambda_s}{\lambda_t}$. Let d_t be the net proceeds from providing payments and ω^b_t be banks' real profits, banks choose the inter-temporal assets, intra-period assets, working capital loans, demand deposits, inter-temporal deposits, and reserves to maximize discounted lifetime utility:

$$\lambda_t \sum_{s=t}^{\infty} \beta^{s-t} \frac{\lambda_s}{\lambda_t} \omega^b_s$$

subject to their flow of funds constraint:

$$P_t\omega^b_t + B_{b,t} + \chi_t F^*_{b,t} + \bar{D}_{t-1}(1 + r^d_{t-1}) = B_{b,t}(1 + r_{t-1}) + \chi_t F^*_{b,t-1}(1 + r^*_{t-1}) + \bar{D}_t + d_t, \quad (58)$$

where $d_t = L_t(1 + i^l_t) - D_t + M_t - \eta_t$ and $M_t = q_t\eta_t$. Also given the inside money creation equation $L_t = D_t$ and (7), banks' optimality conditions lead to

$$1 + r_t = \beta^{-1}\frac{c_{t+1}}{c_t}\Pi_{t+1}, \quad (59)$$

$$1 + r^*_t = \beta^{-1}\frac{c_{t+1}\chi_t}{c_t\chi_{t+1}}\Pi_{t+1}, \quad (60)$$

$$1 + r^d_t = \beta^{-1}\frac{c_{t+1}}{c_t}\Pi_{t+1}, \quad (61)$$

$$i^l_t = i_t. \quad (62)$$

Because banks use inter-temporal interest-bearing time deposits $\bar{D}_t$ to fund their investments in inter-temporal assets, and given our assumption that central bank notes directly held by households are in net zero supply, households' budget constraint is modified as

$$\begin{aligned} P_t c_t + \bar{D}_t + B_t + \chi_t F^*_{h,t} + T_t \\ = (1 + r^d_{t-1})\bar{D}_{t-1} + (1 + r_{t-1})B_{t-1} + \chi_t(1 + r^*_{t-1})F^*_{h,t-1} + W_t n_t + \Omega_t, \end{aligned} \tag{63}$$

where $\Omega_t = \Omega^f_t + P_t \omega^b_t$. Let $B_{hb,t}$ be the total quantity of government bonds held by the households and banks, and $F^*_{hb,t}$ the total quantity of US dollar assets held by the households and banks, then $B_{hb,t} = B_t + B_{b,t}$ and $F^*_{hb,t} = F^*_{h,t} + F^*_{b,t}$. The government budget constraint and the output market clearing condition are modified as (64) and (65) respectively.

$$(1 + r_{t-1})B_{hb,t-1} - B_{hb,t} = T_t + m_{t-1}, \tag{64}$$

$$c_t + \frac{1}{P_t}\chi_t(F^*_{hb,t} - (1 + r^*_{t-1})F^*_{hb,t-1}) = y_t. \tag{65}$$

As before, we combine households' budget flow (63), banks' budget flow (58), firm profits (11), the government budget (64) and output clearing (65), and it follows that Equation (24) still holds. With (24), we still obtain the same IS curve and AD curve (38), the equations used to derive the LM curve (39) and the AS curve (41) remain intact, and the BP curve remains the same as before. Therefore, our model mechanism carries through even when we allow banks to invest in inter-temporal financial assets and sell short-term assets to the central bank at a discount to obtain reserves.