International Reserves for Emerging Economies: A Liquidity Approach

Kuk Mo Jung
Henan University

Ju Hyun Pyun
Korea University Business School

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ABSTRACT

The massive stocks of foreign exchange reserves, mostly held in the form of U.S. T-bonds by emerging economies, are still an important puzzle. Why do emerging economies continue to willingly loan to the United States despite the low rates of return? We suggest that a dynamic general equilibrium model incorporating international capital markets, characterized by decentralized trade and U.S. T-bonds as facilitators of trade, can provide one possible resolution to this question. Declining financial frictions in these over-the-counter (OTC) markets would generate rising liquidity premium on U.S. T-bonds, thereby causing low U.S real interest rates. Meanwhile, the superior liquidity properties of the U.S. T-bonds would induce recipients of foreign investments, namely emerging economies, to hold more liquidity, that is U.S. T-bonds, in equilibrium. The prediction of our model is confirmed by an empirical simultaneous equations approach considering an endogenous relationship between OTC capital inflows and reserve holdings.

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Keywords: international reserves, over-the-counter markets, liquidity, simultaneous equations

E-mail: kmjung@ucdavis.edu, jhpyun@korea.ac.kr.
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1 Introduction

International reserves, mostly held in the form of U.S. T-bonds by emerging economies, are thought to have played a major role in shaping global financial flows and real interest rates over the last decade. However, economists are still unclear about the root causes of the rapid growth in reserve holdings by emerging economies. Most economists studying this topic point to either risk or policy-related factors. The risk approach stresses the hedging role of reserve assets against random sudden stops, whereas the policy approach focuses on reserve assets as a tool in a policy of currency undervaluation.[1]

Although these explanations admittedly provide important insights, one major challenge with them is that the calibrated versions and/or forecasts of their models usually fail to match the sheer size and trend of many emerging markets' reserve accumulation by a large margin. Some even call this failure an *excess reserve accumulation puzzle* (Summers, 2006; Jeanne and Ranciere, 2011). In an attempt to solve this puzzle, others have offered new theories of international reserve determination, emphasizing the role of structural changes in global economic systems and financial market conditions since late 90s.[2] Nevertheless, we believe that the literature is still incomplete in two dimensions. First, it lacks a fully-fledged analysis on the equilibrium relationship between reserve accumulation, interest rates, and net foreign asset positions. Second, most existing theories have largely neglected a very important attribute of the reserve assets, *liquidity*.

The starting point of this paper is, therefore, to postulate that reserve assets possess liquidity properties, because they can help emerging economies facilitate trade for foreign investments in international capital markets. It should be noted that our notion of liquidity is closely linked to the one adopted by modern monetary theory, and refers to the ease with which an asset can help agents purchase consumption. While money is the most obvious example of assets that

[1] For a more comprehensive literature review, see Bernanke (2005); Lane and Milesi-Ferretti (2007a); Ghironi, Lee, and Rebucci (2007); Gourinchas and Rey (2007); McGrattan and Prescott (2007); Warnock and Warnock (2009); Obstfeld, Shambaugh, and Taylor (2010), and Aizenman, Cheung, and Ito (2015).

[2] See, for example, Bird and Rajan (2003), Rodrik (2006), Aizenman and Lee (2008), Cheung and Qian (2009), Obstfeld, Shambaugh, and Taylor (2010), Steiner (2013), Cheng (2015), and, Aizenman, Cheung, and Ito (2015).

can help agents carry out transactions, it is definitely not the only one.[3]

Though we are the first to formalize the asset liquidity in a model of international reserve determination (and bring it to the data), this idea is not completely new. As a matter of fact, it is traced back to Dooley, Folkerts-Landau, and Garber (2004). They argue that the purchase of U.S. T-bonds by China's central bank, for example, is effectively equivalent to financing U.S. foreign investment into China.[4] We can also find more detailed empirical evidence that reserve assets could *effectively* serve as a medium of exchange for foreign capital inflows. China's joint ventures are a case in point.

A joint venture in China is an OTC form of foreign investment where a foreign investor and a state-owned local Chinese company negotiate and agree to develop a new entity in a bilateral fashion. A key point here is that U.S. T-bonds held by the Chinese government play a major role in making joint ventures as safe bets, thereby facilitating foreign investment inflows into China. More precisely, such a role can be categorized into two types; *a source for U.S. dollar lending to joint ventures*, and *a facilitator for remittances of profits as well as repatriation of funds*. The former role arises since U.S. dollar holdings by the national government serve as a major funding source for foreign currency loans made to joint ventures.[5] Unlike the former, the latter role is more about a collateral role of the reserves. This is so because U.S. dollar holdings by state-owned banks guarantees a smooth transfer of funds and profits back home.[6]

Motivated by these pieces of evidence, we construct a two-country dynamic general equilibrium (DGE) model of reserve determination. To isolate this liquidity role of reserves, we

[3] This liquidity notion actually intends to capture a wider range of asset classes than money. For instance, certain types of assets, e.g., bonds and houses, can be used as collateral to generate the consumption utility in the case of collateralized-credit transactions such as repurchase agreements, see Lagos (2010) and Lagos (2011).

[4] *"This acquisition of foreign assets (U.S. T-bonds) favors the importing country (U.S.) in general rather than just the (U.S.) foreign investor. The foreign investor then has to borrow in the importing country at his own normal (and potentially lower) cost of funds, and then buy yuan to make the investment (into China)."* on page 13 in Dooley, Folkerts-Landau, and Garber (2004).

[5] China allows joint ventures to borrow foreign currency (FX) loans from designated state-owned Chinese banks (Bank of China for the most part). This amount varies depending on the size of total investment, and up to 70% of total investment can be financed from those Chinese banks, e.g., Folta (2005), Bosshart, Luedi, and Wang (2010) and Baker and McKenzie (2007) for details.

[6] To be more precise, the Renminbi is not yet freely convertible into other currencies, the foreign party within a joint venture faces a huge illiquidity issue when trying to transfer profits back home. Yet, China also allows joint ventures to convert Renminbi into foreign currencies (mostly U.S. dollar) for remittances of after-tax profits or dividends to foreign investors in the case of equity joint ventures or repatriation of funds in the case of early project termination. Again, this conversion is only permitted through designated state-owned Chinese banks, see Baker and McKenzie (2007) for detailed legal procedures.

work with a liquidity-based model that abstracts entirely from risk considerations such as sudden stops, exchange rate risks, and precautionary motives. We use this framework to study how reserve accumulation, interest rates, and net foreign asset positions jointly evolve in response to changes in macro fundamentals, such as financial frictions in international capital markets and the supply of U.S. T-bonds. To reliably incorporate reserve asset liquidity into a DGE framework, we bring insights from a new branch of monetary economics—with Lagos (2010) at the forefront—that pioneers a new asset pricing model for which assets, in addition to the discounted value of future dividend streams, can be valued for their endogenous liquidity properties. We take this insight further and apply it to a global portfolio choice problem with endogenous changes in reserve assets' liquidity property.

The theoretical prediction of our model is very transparent. The sustained enhancement of reserve assets' liquidity may hold the key to understanding the recent upward trend in reserve accumulation by many emerging economies. Emerging economies seek to make contracts with developed countries to bring foreign capital through international capital markets. Importantly, in the present model, these markets do not use a centralized trading mechanism, such as an exchange. Instead, agents from emerging and developed countries meet in a bilateral fashion and negotiate the terms of trade. Owing to imperfect credit and limited commitment, reserve assets can naturally emerge as a medium of exchange (MOE) for the acquisition of foreign capital.

Within this framework, reserve assets, that is U.S. T-bonds, can carry a *liquidity premium*, which reflects their ability to facilitate transactions in international capital markets. A process of declining frictions, such as, financial deregulation, in these markets expedites trade between agents. This enhances the liquidity premium on the reserve asset and, thus, leads to low rates of return in equilibrium. In this context, agents from emerging markets value the reserve assets' higher liquidity properties more than their counterparts do. This is because foreign agents, being providers of foreign capital, do not require any liquidity services from reserve assets in the international capital markets. Eventually, this increases the equilibrium level of reserve hoarding by home agents.

Note that this new liquidity-based explanation relies on the premise that international capital markets are characterized by decentralized trading. This assumption is by no means a pure theoretical abstraction as shown in the China's joint venture example earlier. Further, the global economy has recently witnessed the emergence of foreign capital inflows into emerging economies, especially those associated with newly developed financial instruments, such as hedge fund investments, leveraged buyout funds by private equity firms, wholesale funding by multinational investment banks, and so on. What is crucial is that these new types of private investment inflows (consistent with the present model's assumptions) are mostly carried out through OTC markets, such as those described in Duffie, Gârleanu, and Pedersen (2005).

Another novel contribution of this study is that we conduct a quantitative empirical analysis to further justify the model framework, as well as associated predictions. First, we construct various measures for aggregate OTC inflows for data of 71 emerging and developing economies from 1990 to 2011 using their debt and FDI inflows. We also introduce a new measurement for OTC flows based on venture capital inflows, which is collected from the FactSet database. Then, we inspect the relationship between OTC inflows and reseve holdings in accordance with our theoretical predictions. Our testable hypothesis from the model is that foreign OTC inflows, triggered by a decline in financial frictions, should be tightly linked to the recent upsurge in emerging markets' reserve holdings. In order to account for endogeneity and simultaneity between reserve holdings and OTC inflows, we adopt a simultaneous equation estimation approach, following Imbs (2004). Through various robustness checks, we find strong empirical support for our liquidity-based hypothesis of international reserve determination.

2 Related Literature

Analyzing reserve accumulation from the viewpoint of liquidity adds new insights to the existing literature. Some prominent studies, such as, Caballero, Farhi, and Gourinchas (2008); Mendoza, Quadrini, and Rios-Rull (2009), emphasize local assets' lack of pledgeability or emerging markets' financial underdevelopment as major sources of the excess global demand for U.S. assets, such as U.S. T-bonds. However, these arguments are not entirely satisfactory given that the rapid reserve accumulation trend does not seem to have slowed down even in the aftermath of the U.S. financial market turmoil and the U.S. debt-ceiling fiasco.[7] By restricting the two-country model to a symmetric financial asset case in terms of pledgeability aspects, our model does not suffer from the same problem. The liquidity-based theory provides a more natural way of supporting sustained reserve accumulation even in the aftermath of the U.S. asset crisis.

Another advantage of our approach is that it provides a framework that is not specific to East Asia. Aizenman and Marion (2004); Durdue, Mendoza, and Terrones (2007); Jeanne and Ranciere (2011) argue that a series of emerging market crises in the 1990s gave rise to East Asia's extraordinary demand for foreign reserve assets. Meanwhile, Summers (2006) and Dooley, Folkerts-Landau, and Peter (2005) suggest that reserve accumulation is a direct consequence of East Asia's industrial policies aiming to achieve undervalued currencies. However, China and India were not hit by the Asian financial crisis, and many East Asian countries switched to an almost fully flexible exchange regime after the crisis.[8] In this regard, the present model complements East Asian-based explanations by providing an extra liquidity channel through which demand for reserve assets can be boosted.

Cheung and Qian (2009) and Qian and Steiner (2014) are two most similar studies to ours in terms of the facilitator role that international reserves play. Cheung and Qian (2009) show that international reserves serve as a barometer of financial health and, thus, facilitate foreign capital inflows and foreign direct investment (FDI). Qian and Steiner (2014) take this facilitator role further. They argue that reserves can even change the risk premium of foreign portfolio equity investment (PEI), thereby altering the composition of foreign capital inflows between FDI and PEI. Our approach differs to theirs in that we specifically evaluate the relationship between reserves and OTC inflows both theoretically and empirically, which no other existing studies have attempted.

As already pointed out, this study attempts to bring intuitive insights from the growing monetary search literature that studies the broader notion of assets as facilitators of trade,

[7] Dominguez (2010) argues that government reserve accumulation plays a role in relaxing financial constraints of private agents in the underdeveloped financial markets, so excessive reserve accumulation in developing countries is related to their financial market underdevelopment.

[8] Furthermore, empirical evidence is not in favor of their arguments on many occasions. See Aizenman and Lee (2007) for the mixed empirical evidence on the conventional explanations.

e.g., Geromichalos, Licari, and Suarez-Lledo (2007); Lagos and Rocheteau (2008); Lagos (2011); Lester, Postlewaite, and Wright (2012); Geromichalos, Herrenbrueck, and Salyer (2013) and Geromichalos and Jung (2015). As in our study, some of these studies extend these insights by applying the notion of asset liquidity to traditional macro puzzles related to asset pricing and portfolio choice theory. Lagos (2010) proposes a framework enriched with aggregate dividend shocks to resolve the *equity premium* puzzle. Geromichalos and Simonovska (2014) bring the monetary search literature closer to questions related to international portfolio diversification. Jung and Lee (2014) adopt a two-country monetary search framework where both money and nominal bonds serve as a media of exchange, and investigate if endogenous liquidity properties of both assets could explain the uncovered interest parity puzzle. Compared to these studies, a main contribution of the present study is to explore how the OTC international capital market affects interest rates and the asymmetric distribution of asset holdings across countries.

The remainder of the paper is organized as follows. Section 3 describes the physical environment of our model. Section 4 explains the optimal behavior of agents in the economy. Section 5 characterizes the equilibrium. Section 6 sets up a testable hypothesis for the proposed model, formulates empirical specifications, and presents the estimation results. Concluding remarks follow in Section 7.

3 Physical Environment

Time is discrete, and the horizon is infinite. There are two countries: home and foreign. The home country represents a developing country, i.e., China, whereas the foreign country represents a developed country, i.e., the United States. Each country has a unit measure of agents who live forever. For notational simplicity we shall henceforth call the home and foreign agents H and F, respectively.

Each period is divided into three sub-periods for which economic activities differ. During the first sub-period, every agent—regardless of where she resides—is endowed with a production technology that allows her to transform each unit of labor into a unit of *numeraire goods*. These goods are identical, so all agents are basically self-sufficient in *numeraire goods* consumption. However, the agents can also choose to trade these goods for two different financial assets: home and foreign assets. What is critical here is that trade for financial assets in this sub-period takes place in one centralized, or Walrasian, market (CM).

The two financial assets are perfectly divisible and are meant to represent emerging market debt and U.S. T-bonds, respectively. For tractability, Lucas (1978) trees are adopted. In each country, a new set of trees is born in the CM every period. Each unit of the tree delivers one unit of numeraire goods in the next period's CM, and then it dies. This simplifies the maturity of both bonds to one period. Any agent can purchase and trade shares of these trees at the ongoing market prices: ψ and ψ^* for home and foreign assets, respectively. The supply of these trees for each country is fixed over time and is denoted by T and T^*, respectively.[9]

During the second sub-period, H and F both visit the foreign investment market (FIM) to engage in anonymous bilateral trade with search frictions; thus, FIM is an OTC market. Importantly, it is assumed that only F is endowed with the technology to produce *capital goods*, from which H obtains utility, thus motivating H and F to trade with each other.[10] Emerging economies benefit from these goods for a variety of reasons, such as employment opportunities and positive technology spillovers. These benefits explain why H seeks to acquire the capital goods from F in the model. In this sense, the recipient of foreign investment projects, i.e., H is identified as a buyer, whereas F is labeled as a seller in this FIM.

Also note that, it is assumed that an exchange in the FIM requires a medium of exchange (MOE). We take a reduced form approach by assuming only foreign assets—namely, U.S. T-

[9] One could instead introduce multi-period bonds, which would not change the qualitative implications of our model. The one-period bond assumption is imposed purely for simplification. Furthermore, it is true that this risk less Lucas (1978) tree asset is not, strictly speaking, the same as U.S. T-bonds in practice. For instance, the U.S. T-bonds are exposed to interest rate risks, and second they are not in fixed supply. These features will surely affect emerging economies' the motives to hold international reserves for emerging economies. However, as already mentioned, we only focus on the liquidity characteristics of the U.S T-bonds without risk considerations. Making the asset characteristics richer and/or more "realistic" with those risk considerations would definitely be an interesting exercise. However, that would be beyond the scope of this paper. We leave that task for future research.

[10] One could interpret the "foreign capital goods" as an indirect utility that home agents enjoy from foreign investment projects for building infrastructure, enhancing local firms' management skills and knowhow, developing financial market structures, and so on. Similar to Aruoba, Waller, and Wright (2011), we could have let foreign capital goods actually be capital and be a factor of production in the forthcoming local decentralized markets. However, this approach would increase the complexity of the already non-trivial bargaining solution during the second sub-period, which in turn would complicate the equilibrium analysis. For this reason, we keep the reduced form assumption that foreign capital directly generates utility for home agents during the second sub-period.

bonds—can serve as a direct MOE.[11][12]. Lastly, for simplicity, this model abstracts from bargaining considerations. Accordingly, the buyer, H is assumed to make a *take-it-or-leave-it offer* to the seller, F, in any bilateral meeting.

In the third sub-period, all agents are back in their local country and visit their own decentralized markets (DMs), where bilateral and anonymous trade for specialized goods takes place. This restriction precludes our model from considering international goods trade. Following Lagos and Wright (2005), goods here shall be called *(special) local goods*. Since the key liquidity mechanism of this model is derived from the FIM, the DMs are set up to be as simple as possible. The two DMs are symmetric. Analogous to the FIM, exchange has to be *quid pro quo*, and only local assets can serve as the means for payment in the DM.[13] Furthermore, the *take-it-or-leave-it offer* by the buyer of the special goods is again assumed.

Time preference with a parameter $\beta \in (0, 1)$ applies only between periods but not between sub-periods. H consumes in all sub-periods, and she supplies labor in the first and third sub-periods. Let $\mathcal{U}^H(x, X, l, L, \kappa)$ represent H's preferences, where x and X are consumption in the DM and CM, respectively, while l and L denote labor hours in the DM and CM, respectively. Last, κ captures the amount of capital goods obtained from F in the FIM. Agent F consumes only in the first and third periods, and she supplies labor in the second and third sub-periods. Let $\mathcal{U}^F(x, X, l, L, h)$ represent F's preferences, where the only new variable is h, which denotes the labor units employed in the FIM. Following the traditional monetary search literature, the quasi-linear utility functional form is adopted as follows. $\mathcal{U}^H(x, X, l, L, \kappa) = U(X) - L + u(\kappa) + u(x) - l$ and $\mathcal{U}^F(x, X, l, L, h) = U(X) - L - c(h) + u(x) - l$. Thus, the

[11] This assumption of reserve assets, namely, U.S. T-bonds, being used as a direct medium of exchange instead of serving a more practically plausible role, such as collateral, can be justified on the grounds of recent monetary search literature. Lagos (2011); Venkateswaran and Wright (2013); Geromichalos, Lee, Lee, and Oikawa (2015); Geromichalos and Herrenbrueck (2016) demonstrate that assets can effectively act as media of exchange despite multiple contractual differences, e.g., collateral, REPO, and secondary OTC assets. Furthermore, employing the model with assets as a direct medium of exchange can avoid unnecessary complexities.

[12] Deeper insights into why U.S. assets may be a superior means of payment in transactions have been offered in the literature. Devereux and Shi (2013) construct a dynamic general equilibrium model of a vehicle currency where agents prefer an indirect trade using the U.S. dollar to a direct trade using their own currencies. One could also refer to the intuition of Rocheteau (2011) and Lester, Postlewaite, and Wright (2012) where asymmetric information on different assets would give rise to one particular asset as a sole medium of exchange.

[13] We do not intend to offer a theory as to why only local assets are accepted as a means of payment. In this regard, we suggest seeing Geromichalos and Simonovska (2014) who show that local assets can indeed endogenously arise as a superior medium of exchange in local markets with an introduction of tiny transaction costs associated with local trade using foreign assets.

usual assumption for the utility and cost functions in the literature applies: $u' > 0, U' > 0, u'' < 0, U'' < 0, U'(0) = u'(0) = +\infty, c' > 0, c'' > 0$.[14]

Next, search frictions in the FIM and DM need to be defined. First, in the FIM, a random match between H and F is assumed with a matching function, $M(B,S)$, which indicates the total number of matches in the FIM when the masses of buyers and sellers equal B and S respectively. This matching function, M, is assumed to increase in both arguments and is homogeneous of degree one. As a result, the arrival rate of buyers (sellers) to an arbitrary seller (buyer), χ_f and χ_h respectively, can be expressed as follows. $\chi_f = M(B,S)/S = M(B/S, 1) \equiv f(\theta)$ and $\chi_h = M(B,S)/B = M(1, S/B) \equiv \theta\chi_f$, where θ is market tightness, and equals S/B. Finally, it is assumed that buyers always visit the FIM and sellers get to visit the FIM with probability $\delta \in (0,1)$, which is meant to capture the degree of international financial market integration. Under this assumption, market tightness is then given by $\theta = \delta/1 = \delta$.

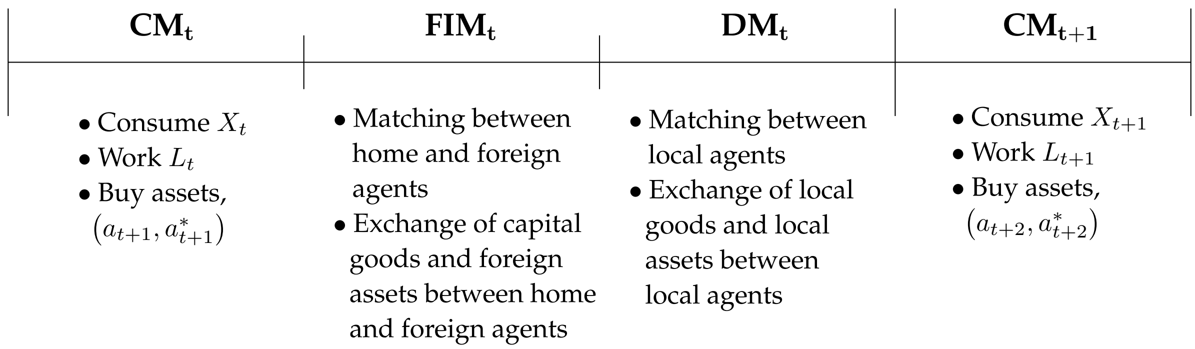
Search frictions in the DM closely follow Lagos and Wright (2005). In each of the DMs, two agents i and j are drawn at random. This leads to three possible events. The probability that i consumes what j produces, but not vice versa—namely, a single coincidence is denoted as σ. Symmetrically, the probability that j consumes what i produces but not vice versa is also σ. In a single-coincidence meeting, the agent who wishes to consume is called the buyer and the agent who produces is called the seller. The probability that neither wants anything the other produces is $1 - 2\sigma$, which implies $\sigma \leq 1/2$.[15] Last, σ is assumed to be symmetric across the two countries. Figure 1 summarizes the timing of the events in this model economy.

We conclude by addressing one potential concern about our model framework. As will be shown in Section 5, a falling search friction in the FIM would be associated with increasing foreign asset holdings by the home country and a rising foreign asset price in equilibrium. From a theoretical point of view, a standard international RBC model augmented with an exogenous pledgeability constraint of the Kiyotaki and Moore (1997) variety could easily generate the same prediction as ours if one assumes some exogenous factors that continuously reduce trading costs within international capital markets. Also, it is true that we impose some *ex-ante*

[14] For simplicity, it is assumed that $c(l) = l$, which is of no importance for our main implications.

[15] The last potentially possible case, wherein both parties like what the other produces, is ignored for simplicity.

Figure 1: Timing of Events



structures, such as reserve assets' serving as a sole MOE in international capital markets just like the Walrasian-based DGE framework with the *ad-hoc* cash-in-advance (CIA) constraint. We embrace this concern that could somewhat limit our theoretical contribution to the literature. However, as stressed so far, the focus of our paper lies in the relationship between reserve accumulation and *bilaterally* transacted or OTC foreign capital inflows. The Walrasian-based DGE framework with some CIA-type constraints would not be able to capture this simply because it lacks a tool to analyze bilateral trading features in international capital markets. At best, It could generate the relationship between *total* FDI inflows and reserve accumulation, which has mixed empirical evidence, e.g., Cheung and Ito (2009). In short, the alternative Walrasian-based international monetary real business cycle model would not be able to justify the empirical evidence found in this paper.

4 Value Functions and Optimal Behavior

Let us begin with an agent's value function in the CM. Consider H who enters this market with a portfolio of home and foreign assets (a, a^*). The Bellman's equation is then expressed by

$$W^H(a, a^*) = \max_{\{X, L, \widehat{a}, \widehat{a}^*\}} \left\{ U(X) - L + \Omega^H(\widehat{a}, \widehat{a}^*) \right\},$$

$$s.t.\;\; X + \psi \widehat{a} + \psi^* \widehat{a}^* = L + a + a^*,$$

where ψ and ψ^* stand for the prices of home and foreign asset respectively and variables with hats denote next period's choices. It can be easily verified that, at the optimum, $X = \bar{X}$. Replacing L from the H's budget constraint into $W^H(a, a^*)$ yields

$$W^H(a,a^*) = U(\bar{X}) - \bar{X} + (a+a^*) + \max_{\{\widehat{a},\widehat{a}^*\}} \big\{ -\psi\widehat{a} - \psi^*\widehat{a}^* + \Omega^H(\widehat{a},\widehat{a}^*)\big\}. \tag{1}$$

It is important to note that no wealth effects for the H's portfolio choice exists following from the quasi-linearity of $\mathcal{U}$. Furthermore, $W^H(a,a^*)$ can be simplified as

$$W^H(a,a^*) = \Lambda^H + a + a^*. \tag{2}$$

Next, consider F's Bellman's equation. Regarding her asset holdings, she is assumed to carry no home assets as she leaves the CM for simplicity.[16] Thus, when the F enters the CM, she can only hold foreign assets that she received during trade in either of the preceding FIM and DM, i.e., a^* is the only state variable for F. This gives the CM value function of F as

$$W^F(a^*) = \max_{\{X,L,\widehat{a}^*\}} \big\{U(X) - L + \Omega^F(\widehat{a}^*)\big\},$$

$$s.t.\ \ X + \psi^*\widehat{a}^* = L + a^*.$$

Since $X = \bar{X}$ at the optimum again, the Bellman's equation for F can be rewritten as

$$W^F(a^*) = U(\bar{X}) - \bar{X} + a^* + \max_{\{\widehat{a}^*\}} \big\{ -\psi^*\widehat{a}^* + \Omega^F(\widehat{a}^*)\big\}. \tag{3}$$

The quasi-linearity assumption also simplifies the e.q.(3) as an affine function[17]

$$W^F(a^*) = \Lambda^F + a^*. \tag{4}$$

Once the CM closes, both proceed to the FIM. The matching probabilities (or arrival rates) for the two types of agents (H and F) are exogenously given by χ_h and χ_f. Let κ denote the amount of capital goods transferred from F to H in the FIM, while b^* stands for the total units of foreign assets received by F in exchange for the κ given to H. These terms will be determined through bargaining which will be studied in details later. For now, it is understood that b^* and κ will, in general, be functions of the foreign asset holdings of both H and F within a match. Let $\widetilde{a}^*$ denote the amount of foreign asset holdings that an agent expects a potential counterparty to carry. The following then shows the value functions for H and F during the FIM.

[16] Intuitively, the F does not require any liquidity service from home assets in any of the FIM and her local DM. However, there may be a case where the cost of carrying home assets becomes zero in equilibrium. In this case, F may choose to hold home assets purely as a savings instrument. In order to avoid this situation, one could possibly introduce an infinitesimally small cost of participating the CM in line with Chiu and Molico (2010). This would ensure no home asset holdings by the F all the time. One can also refer to Rocheteau and Wright (2005) for a careful proof of the result that sellers do not hold any means of payment.

[17] The definition of Λ^H and Λ^F are obvious from e.q.(1) and (3) respectively.

$$\Omega^H(a,a^*) = \chi_h\big\{u(\kappa) + V^H(a,a^*-b^*)\big\} + (1-\chi_h)V^H(a,a^*), \tag{5}$$

$$\Omega^F(a^*) = \chi_f\big\{V^F(a^*+b^*) - c(\kappa)\big\} + (1-\chi_f)V^F(a^*), \tag{6}$$

where V^H and V^F denote a value function for H and F respectively in the following local DMs, and $\kappa = \kappa(a^*, \widetilde{a}^*)$, $b^* = b^*(a^*, \widetilde{a}^*)$.

Finally consider value functions in the last sub-period. For the home country's local DM, let $F(\widetilde{a})$ be the distribution of home asset holdings among home agents. Let q also be the quantity of *(special) local goods* produced by the seller, and n the total payment in the units of home assets, made to the seller by the buyer. These terms will also be determined through bargaining explained later. The Bellman's equation then is

$$\begin{aligned} V^H(a,a^*) =& \sigma\left\{u(q(a)) + \beta W^H(a-n(a),a^*)\right\} + \sigma\int\left\{-q(\widetilde{a}) + \beta W^H(a+n(\widetilde{a}),a^*)\right\}dF(\widetilde{a}) \\ &+ (1-2\sigma)\beta W^H(a,a^*), \end{aligned} \tag{7}$$

where $q = q(a)$ and $n = n(a)$. The first component in the righthand side of the above equation captures the payoff from buying $q(a)$ and going to the next period's CM with asset holdings of $(a - n(a), a^*)$. The second one means the expected payoff from selling $q(\widetilde{a})$ and going to the next period's CM with $(a + n(\widetilde{a}), a^*)$. It is easy to see that only the amount of assets that the buyer brings into the DM matters for the determination of the terms of trade. The last one is the payoff from going to the next period's CM with no trade history in the current DM. Using the same intuition, the Bellman's equation for F can be expressed as

$$\begin{aligned} V^F(a^*) =& \sigma\left\{u(q(a^*)) + \beta W^F(a^*-n(a^*))\right\} + \sigma\int\left\{-q(\widetilde{a}^*) + \beta W^F(a^*+n(\widetilde{a}^*))\right\}dF(\widetilde{a}^*) \\ &+ (1-2\sigma)\beta W^F(a^*). \end{aligned} \tag{8}$$

Having figured out the value functions for all agents, we describe how the terms of trade in the DM and FIM are determined respectively. Since the DM follows after the FIM, the terms of trade in the FIM should be critically affected by the terms of trade in the DMs. For this reason, backward induction is employed. Following the previous section, the terms of trade in any bilateral meeting within the home DM are $\{q(a), n(a)\}$, where a is the amount of home asset holdings that the buyer has brought into the bargaining. With *take-it-or-leave-it* (TIOLI) offers by the buyer, the bargaining problem is then

$$\max_{\{q,n\}} \left\{ u(q) + \beta \left[W^H (a - n, a^*) - W^H (a, a^*) \right] \right\},$$

$$s.t. \;\; 1. \;\; q \leq \beta \left[W^H (a + n, a^*) - W^H (a, a^*) \right],$$

$$2. \;\; n \leq a.$$

The buyer aims to maximize the *(special) local goods* consumption utility. At the same time, she also needs to minimize the loss from giving up n in exchange for q in a present discounted form. This is what the objective function in the bargaining problem describes. By the same logic, gains from obtaining n must be greater than or equal to the cost of producing q for the seller. Moreover, the amount of assets handed over to the seller can not exceed what the buyer owns at the time of negotiation. These explain the two budget constraints. Exploiting the linearity of the $W^H(a, a^*)$ in e.q.(1), the bargaining problem can be rewritten as

$$\max_{\{q,n\}} \left\{ u(q) - \beta n \right\},$$

$$s.t. \;\; q = \beta n,$$

with the resource constraint, $n \leq a$. By the symmetric DM assumption across two countries, the bargaining problem in the foreign country's local DM can be written and solved identically.The following lemma describes the bargaining solutions during the two DMs in detail.

Lemma 1. *Define* $\tilde{q} = \{q : u'(q) = 1\}$ *and* $\breve{a} = \tilde{q}/\beta$. *Bargaining solutions for the home and foreign country's DM are respectively given by* $q(a) = \min\{\tilde{q}, \beta a\}$, $n(a) = \min\{\breve{a}, a\}$, $q^*(a^*) = \min\{\tilde{q}, \beta a^*\}$, *and* $n^*(a^*) = \min\{\breve{a}, a^*\}$.

Proof. It can be easily verified that the suggested solution satisfies the necessary and sufficient conditions for maximization. □

Due to no hold-up problem understanding the lemma above is straightforward. Bargaining solutions critically depend upon the buyer's local asset holdings brought into the bargaining. When her local asset holdings are short of the threshold level, $\breve{a}$, she would purchase as much q as her local assets holdings allow. On the contrary, if her local asset holdings are greater than or equal to $\breve{a}$ then, she would only spend a portion of the assets such that she could purchase only up to the optimal amount of $\tilde{q}$.

Now, consider a meeting in the FIM between H with foreign asset holdings of a_h^* and F with a_f^*. Assuming again the TIOLI offer by H, the bargaining problem is given by

$$\max_{\{\kappa,b^*\}} \left\{u(\kappa) + \left[V^H\left(a, a_h^* - b^*\right) - V^H\left(a, a_h^*\right)\right]\right\},$$

$$s.t.\ c(\kappa) \leq \left[V^F\left(a_f^* + b^*\right) - V^F\left(a_f^*\right)\right],$$

with a resource constraint, $b^* \leq a_h^*$. Intuition of this bargaining problem is identical to the DM case. H chooses the terms of trade to maximize her surplus subject to the participation constraint for F. If one substitutes V^H and V^F from e.q.(7) and e.q.(8) into the expression above, the bargaining problem can be simplified as

$$\max_{\{\kappa,b^*\}} \left\{u(\kappa) - \beta b^*\right\},$$

$$s.t.\ c(\kappa) \leq \beta b^* + \sigma\left[u(q(a_f^* + b^*)) - \beta n(a_f^* + b^*)\right] - \sigma\left[u(q(a_f^*)) - \beta n(a_f^*)\right],$$

with the same resource constraint, $b^* \leq a_h^*$.

It is understood that the $q(\cdot), n(\cdot)$ are described by the solutions to the DM bargaining problem described earlier. The participation constraint for the F in this problem deserves some intuitive explanation. Unlike the DM's bargaining case, the F's gain in exchange for κ comes from two sources: the asset's store of value, i.e., βb^* and medium of exchange value in the subsequent DM, i.e., $\sigma\left[u(q(a_f^* + b^*)) - \beta n(a_f^* + b^*)\right] - \sigma\left[u(q(a_f^*)) - \beta n(a_f^*)\right]$. This constraint turns out to allow the FIM trade to essentially drive the liquidity mechanism of the model later. Lemma 2 summarizes the bargaining solution.

Lemma 2. *Define* $\tilde{\kappa} = \{\kappa : u'(\kappa)/c'(\kappa) = 1\}$. $\bar{a}_f^*$ *is such that* $\sigma u(\beta\bar{a}_f^*) + (1-\sigma)\beta\bar{a}_f^* = \sigma u(\tilde{q}) + (1-\sigma)\beta\breve{a} - c(\tilde{\kappa})$, *where* $\tilde{q}$ *and* $\breve{a}$ *are defined in Lemma 1. Below, we also define* f *as a function of* a_f^* *and* κ *to simplify solutions.*

$$f\left(a_f^*, \kappa\right) = \begin{cases} c(\kappa)/\beta & \text{if } a_f^* \geq \breve{a}, \\ \left\{c(\kappa) - \sigma[u(\tilde{q}) - u(\beta a_f^*) + \tilde{q} - \beta a_f^*]\right\}/\beta & \text{if } \max\{\bar{a}_f^*, \breve{a} - a_h^*\} \leq a_f^* \leq \breve{a}, \\ \left\{f : c(\kappa) = (1-\sigma)\beta f + \sigma\left[u(\beta(a_f^* + f)) - u(\beta a_f^*)\right]\right\} & \text{if } a_f^* \leq \max\{\bar{a}_f^*, \breve{a} - a_h^*\}. \end{cases}$$

Under a parameter space such that $c(\tilde{\kappa}) < \beta\breve{a} + \sigma\left[u(\tilde{q}) - \tilde{q}\right]$, *the bargaining solution is as follows.*[18]

[18] The other potential parameter space case where $\beta\breve{a} + \sigma\left[u(\tilde{q}) - \tilde{q}\right] \leq c(\tilde{\kappa})$ is relegated to technical appendix. As a matter of fact, this second case is nested by the first one. For this reason, only the latter will be considered for the rest of the analysis.

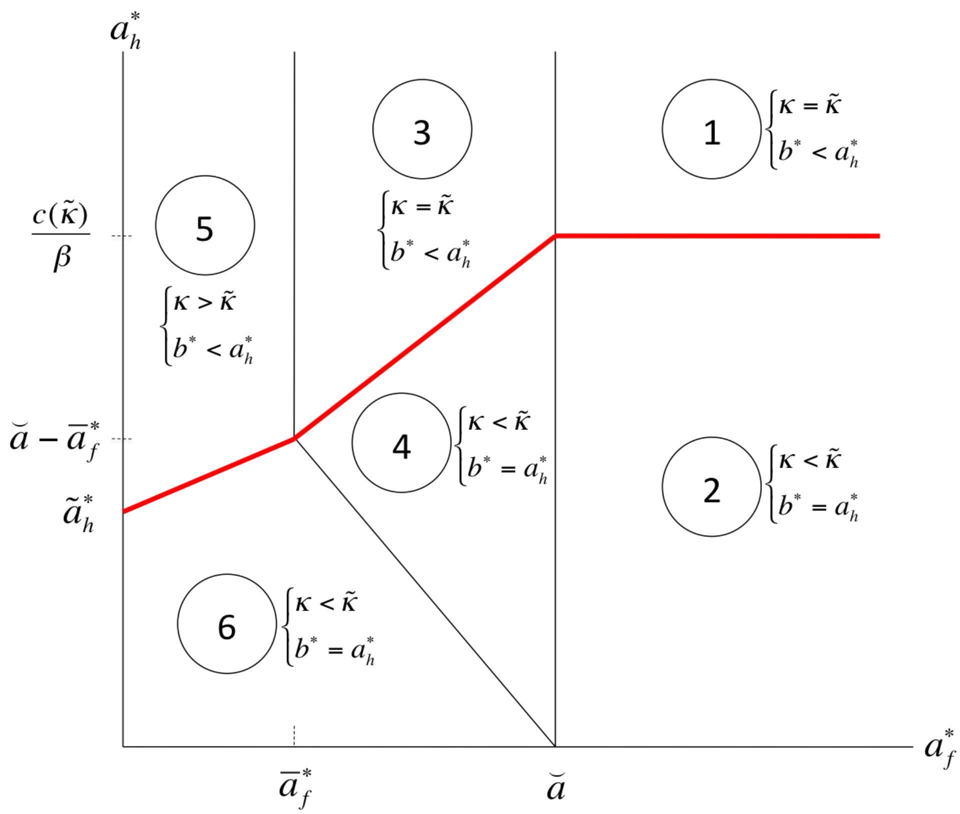
If $a_h^* \leq f\left(a_f^*, \tilde{\kappa}\right)$ then, $\kappa = \left\{\kappa : a_h^* = f\left(a_f^*, \kappa\right)\right\}$ and $b^* = a_h^*$,

If $a_h^* \geq f\left(a_f^*, \tilde{\kappa}\right)$ and $a_f^* \geq \bar{a}_f^*$ then, $\kappa = \tilde{\kappa}$ and $b^* = f\left(a_f^*, \tilde{\kappa}\right)$,

If $a_h^* \geq f\left(a_f^*, \tilde{\kappa}\right)$ and $a_f^* \leq \bar{a}_f^*$ then, (κ, b^*) is such that $\kappa > \tilde{\kappa}, b^* < a_h^*, b^* < \breve{a} - a_f^*, b^* = f(a_f^*, \kappa)$.

Proof. See technical appendix $\square$

Figure 2: Regions of the FIM Bargaining Solution



Lemma 2 can be intuitively interpreted with an assistance of Figure 2 in which $\tilde{a}_h^*$ is defined as follows. $\tilde{a}_h^* = \{a_h^* : c(\tilde{\kappa}) = \sigma u(q(a_h^*)) + (1-\sigma)\beta a_h^*\}$. First thing to notice here is that the bargaining solution is affected not only by a_h^* but also a_f^*. This feature is again attributed to a specific timing of the FIM and DM introduced in this model. After the FIM, F needs to come back home and to visit the local DM where foreign assets are accepted as means of payment. Knowing this, her participation constraint for accepting the offer from H has to be linked to the liquidity constraint in the subsequent local DM.

Before we explain the bargaining solution in detail, we provide intuition for various terms that appear in Lemma 2. The term $\tilde{\kappa}$ stands for the socially efficient level of output in the FIM.

The threshold level, $\bar{a}_f^*$ is the amount of pre-bargaining foreign asset holdings by F such that the FIM bargaining outcome brings about $\tilde{\kappa}$ and post-bargaining foreign asset holdings of F, equal to $\breve{a}$. F intuitively experiences a shift in the liquidity value of foreign assets around this bliss point. If her foreign assets holdings exceed this point, she would *effectively* enjoy a higher bargaining power. Otherwise, she would become more desperate and, face less favorable terms of trade. Therefore, $\bar{a}_f^*$ critically affects the FIM liquidity constraint for F. The function $f(a_f^*, \tilde{\kappa})$ represents a threshold level of foreign asset holdings of H, which critically depends on the F's foreign asset holdings. As with typical TIOLI bargaining problems in this type of models, H obtains the first best outcome if her asset holdings exceed that threshold level, otherwise she would end up with a less favorable outcome. Naturally, this function is increasing in a_f^*, intuitively implying a lesser degree of desperation for foreign assets by F with greater pre-bargaining level of a_f^*. In fact, the line highlighted in red in Figure 2 exactly corresponds to this threshold function, $f(a_f^*, \tilde{\kappa})$.

Given this discussion, it is intuitive to interpret the FIM bargaining solution. There are 6 regions of different bargaining solutions depending on the combination of $\{a_h^*, a_f^*\}$. Consider the situation where the liquidity holdings of F are plentiful, i.e., the amount of foreign assets held by F already satisfies the first best liquidity amount ($\breve{a}$) in the subsequent local DM. In this case, the H's foreign asset holdings solely determine the terms of trade because the F's expected surplus from obtaining foreign assets during the FIM trade only stems from a store value of the asset (dividend payment in the next period's CM). Given this observation, if the H's foreign asset holdings happen to be greater than or equal to the amount required to purchase the first best $\tilde{\kappa}$, i.e., $a_h^* \geq f\left(a_f^*, \tilde{\kappa}\right)$, then, she would only give up the amount just enough to cover the $\tilde{\kappa}$. On the other hand, if she is short of the amount for the $\tilde{\kappa}$, i.e., $a_h^* \leq f\left(a_f^*, \tilde{\kappa}\right)$, then, she would give up all her foreign asset holdings and purchase κ as much as possible. These two situations are respectively illustrated in region 1 and 2 of Figure 2.

When the F's foreign asset holdings fall short of $\breve{a}$ then, the liquidity factor kicks in to alter the participation constraint for F during the FIM bargaining. Suppose $\{a_h^*, a_f^*\}$ initially lies in region 1, and suddenly a_f^* falls below $\breve{a}$ (region 3). This would enforce the F's liquidity constraint in the subsequent DM to bind. As a result, the F would appreciate the acquisition of foreign assets during the FIM trade more. This in turn would bring about more favorable terms of trade for the H. Therefore the latter would be able to obtain $\tilde{\kappa}$ with less amount of foreign assets handed over compared to the region 1 case. Exactly same reasoning applies to the shift from region 2 to region 4. Given the same amount of foreign asset holdings transferred to F, the latter would agree to provide more κ in region 4 than region 2. Finally, H obtains $\tilde{\kappa}$ in region 3. Yet, she receives less than $\tilde{\kappa}$ in region 4 since she is liquidity constrained in this case, i.e., $a_h^* \leq f\left(a_f^*, \tilde{\kappa}\right)$.

Region 5 represents a situation where the discrepancy between agents' foreign asset holdings is somewhat extreme. In this case, F faces a severe liquidity constraint in the following local DM while H holds a lot of foreign assets. Hence, F's rather extreme desperation for liquidity basically drives up the liquidity property of foreign assets to the point where she would be willing to accept very bad terms of trade, i.e., $\kappa > \tilde{\kappa}$ and $b^* < a_h^*$.[19]

Lastly, region 6 implies the situation in which the liquidity in the economy dries up most. H would give up her entire foreign assets to acquire κ as much as possible. Since the first best liquidity amount for F can not be met anyway even after combining the H's foreign asset holdings, i.e., $a_h^* + a_f^* < \check{a}$, the amount of goods produced would be strictly less than the first best outcome, $\tilde{\kappa}$.

With all bargaining solutions in place, one can proceed to derive the objective function of the representative agent and describe optimal behavior. The aim of the objective function is to figure out agent's optimal portfolio choice. Consider the objective function for H first. To that end, substitute e.q.(7) into e.q.(5) and lead the emerging expression for $\Omega^H(a, a^*)$ by one period. This would generate the following.

$$\Omega^H(\widehat{a}_h, \widehat{a}_h^*) = \beta\widehat{a}_h^* + \chi_h\left[u(\kappa(\widehat{a}_h^*, \widehat{a}_f^*)) - \beta b^*(\widehat{a}_h^*, \widehat{a}_f^*)\right] + \beta\widehat{a}_h + \sigma\left[u(q(\widehat{a}_h)) - \beta n(\widehat{a}_h)\right] + \beta\Lambda^H + \sigma\int\left\{-q(\widetilde{a}) + \beta W^H(n(\widetilde{a}), 0)\right\}dF(\widetilde{a}). \tag{9}$$

The three components of this expression represent different benefits at different sub-periods for H who enters the FIM with a portfolio of $(\widehat{a}_h, \widehat{a}_h^*)$. The first component corresponds to the

[19] Notice here that there even exist some part of region 5 where the sum of foreign asset holdings by both H and F falls short of $\check{a}$, and yet H would get more than $\tilde{\kappa}$

benefit from holding foreign assets until the beginning of next period. The first term indicates the discounted vale of dividends at the next period's CM while the second term shows the net surplus from the FIM trade. Notice that this net surplus depends upon her belief on the F's foreign asset holdings ($\widehat{a}_f^*$) since the latter would affect the FIM terms of trade. The second component analogously stands for the discounted value of home asset dividends as well as the net surplus from participating in the subsequent local DM as a buyer. The last component implies the constant benefit that does not depend on the H's portfolio choice, i.e., next period CM's net consumption utility gain plus the net surplus in the subsequent local DM as a seller.

The next step is to plug e.q.(9) into $W^H(a, a^*)$ in e.q.(1). Focusing on the terms inside the maximum operator of e.q.(1), i.e., ignoring the terms that do not affect the choice variables, one can derive the H's objective function as follows.

$$J^H(\widehat{a}_h, \widehat{a}_h^*) = [-\psi + \beta]\, \widehat{a}_h + [-\psi^* + \beta]\, \widehat{a}_h^* + \sigma \left[u(q(\widehat{a}_h)) - \beta n(\widehat{a}_h)\right] + \chi_h \left[u(\kappa(\widehat{a}_h^*, \widehat{a}_f^*)) - \beta b^*(\widehat{a}_h^*, \widehat{a}_f^*)\right]. \tag{10}$$

Maximization of the above function with respect to $(\widehat{a}_h, \widehat{a}_h^*)$ fully describes the optimal asset holdings of H in every period. Conforming with the literature, the interpretation of e.q.(10) is standard. The first part represents the net cost of carrying one unit of home and foreign assets respectively from today's CM into tomorrow's CM. The second and third part expresses the expected surplus from carrying the home and foreign assets into the DM and FIM respectively.

What is worth noting here is that the third line in e.q.(10) depends on the terms κ and b^*, which in turn depend on the the bargaining protocol in the FIM. Given H's choice of $\widehat{a}_h^*$ and beliefs on the $\widehat{a}_f^*$, she can end up in different branches of the bargaining solution as shown in Lemma 2 and Figure 2. This leads to different functional forms for the $J^H(\widehat{a}_h, \widehat{a}_h^*)$ with respect to the different regions. Lemma 6 in the technical appendix presents an auxiliary result that highlights some important properties of the region specific $J^H(\widehat{a}_h, \widehat{a}_h^*)$.

F's objective function should take a simpler form than the H's since her optimal choice would not depend upon the H's choice at all. Following the same steps as in the H's case, substitute e.q.(8) into e.q.(6) and lead the emerging expression for $\Omega^F(a^*)$ by one period to get

$$\Omega^F(\widehat{a}_f^*) = \beta \widehat{a}_f^* + \sigma \left[u(q(\widehat{a}_f^*)) - \beta n(\widehat{a}_f^*)\right] + \beta \Lambda^F + \sigma \int \left\{-q(\widetilde{a}^*) + \beta W^F(n(\widetilde{a}^*))\right\} dF(\widetilde{a}^*). \tag{11}$$

This expression can be interpreted in a similar manner to the e.q.(9). Notice here that unlike the H's case, F does not appreciate the liquidity properties of foreign assets within the FIM trade since H would exploit the whole surplus from the *take-it-or-leave-it* offer. This fact leads to a lot more concise form of the objective function for F. Plugging e.q.(11) into e.q.(3), one can similarly derive the F's objective function as

$$J^F(\widehat{a}_f^*) = [-\psi^* + \beta]\,\widehat{a}_f^* + \sigma\left[u(q(\widehat{a}_f^*)) - \beta n(\widehat{a}_f^*)\right], \tag{12}$$

where the first term stands for the cost of carrying foreign assets into the local DM and the second term captures the expected surplus term as in e.q.(10).

Based on the two objective functions, one can consider equilibrium characteristics of home and foreign asset prices. As a matter of fact, it would be easy to verify whether the cost of carrying asset terms in e.q.(10) and (12) are non-negative or not in equilibrium. Lemma 7 in the technical appendix does this verification by stating important results regarding the sign of the cost terms in equilibrium.

In what follows, each agent's optimal portfolio choice problem is rigorously studied. First, consider F's problem which is easier. The following lemma describes the optimal portfolio choice of F taking ψ and ψ^* as given.

Lemma 3. *A foreign agent's optimal choice of foreign asset holdings satisfies the following. If $\psi^* = \beta$ then, the optimal foreign asset holdings of F should be greater than or equal to $\breve{a}$. On the other hand, if $\psi^* > \beta$ then, there exists an* ***unique*** *level of foreign asset holdings, $\widetilde{a_f^*}$ such that $\widetilde{a_f^*} \in (0, \breve{a})$ and $\psi^* - \beta = \sigma\beta\left\{u'(q(\widetilde{a_f^*})) - 1\right\}$.*

Proof. See technical appendix □

A standard marginal cost-benefit analysis can be applied to interpret the optimal condition in Lemma 3. F at the optimum must choose to hold the amount of foreign assets such that the marginal benefit $(\sigma\beta\{u'(q(\widetilde{a_f^*})) - 1\})$ equals to the marginal cost of holding additional unit of foreign assets ($\psi^* - \beta$). This optimal condition in turn implies the usual downward sloping asset demand curve, i.e., a negative relationship between ψ^* and $\widetilde{a_f^*}$, due to $u''(\cdot) < 0$. For instance, when the cost of carrying foreign assets falls to zero, i.e., $\psi^* = \beta$, the optimality requires that F should hold the maximum possible amount of the foreign asset, $\breve{a}$.

H's optimal portfolio choice is nontrivial because her own belief on the F's foreign asset holdings would critically affect the objective function, $J^H(\widehat{a}_h, \widehat{a}_h^*)$ as in Lemma 6. Thus, one ought to build on Lemma 6 in order to study the optimal behavior of H in details. Lemma 4 summarizes the results.

Lemma 4. *A home agent's optimal choice of home asset holdings is simple, and satisfies the following. If $\psi = \beta$ then, the optimal home asset holdings of H should be greater than or equal to $\check{a}$. On the other hand, if $\psi > \beta$ then, there exists an **unique** level of home asset holdings, $\widetilde{a}$ such that $\widetilde{a} \in (0, \check{a})$ and $\psi - \beta = \sigma\beta\left\{u'(q(\widetilde{a})) - 1\right\}$. Taking ψ^* given, the H's optimal choice of foreign asset holdings ($\widetilde{a_h^*}$) can be categorized into three different regimes depending on her beliefs on the F's foreign asset holdings.*

Belief 1: $\widehat{a}_f^* > \check{a}$

If $\psi^* = \beta$ then, $\widetilde{a_h^*} = \mathbb{R}_{++} \geq c(\tilde{\kappa})/\beta$.

If $\psi^* > \beta$ then, $\widetilde{a_h^*} = c(\kappa)/\beta$ such that $\psi^* - \beta = \chi_h\beta\left\{u'(\kappa)/c'(\kappa) - 1\right\}$.

Belief 2: $\bar{a}_f^* < \widehat{a}_f^* \leq \check{a}$

If $\psi^* = \beta$ then, $\widetilde{a_h^*} = \mathbb{R}_{++} \geq f\left(\widehat{a}_f^*, \tilde{\kappa}\right)$.

If $\beta < \psi^* \leq \overline{\psi^*}$ then, $\widetilde{a_h^*} = f\left(\widehat{a}_f^*, \kappa\right)$ such that $\psi^* - \beta = \chi_h\beta\left\{u'(\kappa)/c'(\kappa) - 1\right\}$.

If $\overline{\psi^*} < \psi^*$ then, $\widetilde{a_h^*} = f\left(\widehat{a}_f^*, \kappa\right)$ such that $\psi^* - \beta = \chi_h\beta\left\{u'(\kappa)/c'(\kappa)\left\{(1-\sigma) + \sigma u'(\beta\widehat{a}_f^*)\right\} - 1\right\}$.

Belief 3: $\widehat{a}_f^* \leq \bar{a}_f^*$

If $\psi^* = \beta$ then, $\widetilde{a_h^*} = \mathbb{R}_{++} \geq f\left(\widehat{a}_f^*, \tilde{\kappa}\right)$.

If $\psi^* > \beta$ then, $\widetilde{a_h^*} = f\left(\widehat{a}_f^*, \kappa\right)$ such that $\psi^* - \beta = \chi_h\beta\left\{u'(\kappa)/c'(\kappa)\left\{(1-\sigma) + \sigma u'(\beta\widehat{a}_f^*)\right\} - 1\right\}$, where $\overline{\psi^*}$ is such that $\overline{\psi^*} - \beta = \chi_h\beta\left\{u'(\kappa)/c'(\kappa) - 1\right\}$ and $c(\kappa) = \sigma\left[u(\tilde{q}) - \tilde{q}\right] - \sigma\left[u(q(\widehat{a}_f^*)) - q(\widehat{a}_f^*)\right] + \beta(\check{a} - \widehat{a}_f^*)$.

Proof. See technical appendix □

Given the results stated in the Lemma 4, one can describe in detail the demand functions for the home and foreign assets by the H. Although interesting, this analysis is not essential for understanding the main results of the paper, hence, it is relegated to the technical appendix. We are now ready to discuss equilibrium.

5 Equilibrium

5.1 Definition and Existence of Equilibrium

Having established the optimal behavior of the representative agent, the next step is to discuss a recursive equilibrium of the economy. This paper only focuses on the steady state equilibrium and study the equilibrium property associated with effects of different degrees of search frictions in the FIM on equilibrium asset prices and portfolio composition. First, a steady state equilibrium in this model is defined as follows.

Definition 1. *For the two-country economy, a steady state equilibrium is a following list of an allocation* $\{X_i, L_i, a_h, a_i^*, i = \{h, f\}\}$*, together with value functions* $\{V^i, \Omega^i, W^i, i = \{H, F\}\}$*, a set of prices* $\{\psi, \psi^*\}$*, bilateral terms of trade* $\left\{\kappa(a_h^*, a_f^*), b^*(a_h^*, a_f^*)\right\}$ *in the FIM, bilateral terms of trade* $\{q(a_h), n(a_h)\}$ *in the H's local DM, bilateral terms of trade* $\left\{q(a_f^*), n(a_f^*)\right\}$ *in the F's local DM when F was not matched in the preceding FIM, and bilateral terms of trade* $\left\{q(a_f^* + b^*(a_h^*, a_f^*)), n(a_f^* + b^*(a_h^*, a_f^*))\right\}$ *in the F's local DM when F was matched in the preceding FIM such that*

- ✓ *Given prices, the value functions and decision rules satisfy e.q (1), (3), (5), (6) (7), and (8)*
- ✓ *Bargaining solutions in the FIM and DMs satisfy Lemma 1 and 2*
- ✓ *The set of prices is such that all agents maximize their objective functions, e.q (10) and (12)*
- ✓ *Markets for the two assets clear and expectations are rational, i.e.,* $a_h = T$ *and* $a_h^* + a_f^* = T^*$*.*

The definition of equilibrium is straightforward. Notice that the equilibrium quantity of (local) special goods produced in the F's local DM depends on whether the F was matched in the preceding FIM or not. For instance, a foreign agent who did not get matched in the FIM can not purchase the first best amount of special goods, i.e., $\tilde{q}$ in her local DM unless she had brought more than $\breve{a}$ from the preceding CM. However, if she was matched in the FIM then, she would be, on some occasions, able to achieve the $\tilde{q}$ even if her *ex-ante* foreign asset holdings were less than $\breve{a}$ (for example, when (a_h^*, a_f^*) lies within the region 3 or 4). Obviously, on some other occasions when either her foreign asset holdings fall short of $\breve{a}$ to a great extent, e.g., the region 5, or H's foreign asset holdings are too small, e.g., the region 6, she would not be able to obtain the $\breve{a}$ even with the FIM matching. Next, the following lemma guarantees existence of equilibrium and states the conditions under which the equilibrium is unique.

Lemma 5. *If $T^* < \check{a} + c(\tilde{\kappa})/\beta$ then, a unique list of steady state equilibrium objects defined in the Definition 1 exists. Otherwise, $\psi = \psi^* = \beta$, and an indeterminacy arises in the portfolio choice of (a_h^*, a_f^*).*[20]

Proof. See technical appendix □

Lemma 5 can be explained intuitively with Figure 2. If $T^* \geq \check{a} + c(\tilde{\kappa})/\beta$, then the Figure 2 admits that equilibrium portfolio of (a_h^*, a_f^*) ought to lie within the region of 1, 2, 3, or 5. Suppose it lies in the interior of region 2. Here, F owns the first best amount of liquidity for her DM trade and therefore, she would not pay anything more than the fundamental value of the foreign asset, β. Yet, H would still like to pay *liquidity premium* on that asset to get closer to the $\tilde{\kappa}$. This would cause a violation of no arbitrage condition for the foreign asset trade and therefore, no equilibrium portfolio can be achieved in this region.

Similar reasoning applies to the region 3 and 5. In these regions, F lacks liquidity in reference to the first best choice ($\check{a}$) and therefore, must be willing to pay liquidity premium on the foreign asset. H, on the other hand, would not value the asset more than its fundamental value since she always accomplishes at least $\tilde{\kappa}$ in this region. Again, no equilibrium would exist in these regions.

Lastly, if the equilibrium portfolio, (a_h^*, a_f^*) stayed in the region 1, every agents would achieve the first best amount of liquidity for both of the FIM and DM. Hence, the price should settle at the fundamental value, β and any combination of (a_h^*, a_f^*) should satisfy the optimality. This eventually gives rise to a multiple equilibrium of the economy.

When $T^* < \check{a}+c(\tilde{\kappa})/\beta$, it is understood from Figure 2 that the equilibrium portfolio of (a_h^*, a_f^*) could potentially lie anywhere except within the region 1. For the same reason described earlier, the region 2, 3, and 5 are easily ruled out, which leaves only the region 4 and 6 as an equilibrium region. As witnessed again from the Figure 2, neither H nor F would find herself in the plentiful liquidity situation within the region 4 and 6. H would always want more foreign assets to aim for $\tilde{\kappa}$. Similarly F *ex-ante* would like to purchase foreign assets more as well.[21]

[20] The irrelevance of T, the home asset supply, for the uniqueness of the equilibrium is obvious. Intuitively, only home agents purchase home assets, and the T does not affect the FIM bargaining protocol at all.

[21] *Ex-ante* here means 'before the FIM trade'. The fact that foreign agents would be able to make up for the first best liquidity *ex-post*. i.e., after the FIM trade, does not attenuate F's appreciation for the foreign asset's liquidity property. This is simply because F would have to suffer more labor disutility, required for the asset acquisition

This opens up the possibility of a unique market clearing price ψ^*, which can be indeed pinned down by the first-order conditions for both H and F. The uniqueness of this price is simply associated with the well-behaved, i.e. strictly concave, utility functions of agents. Technical details are left in the technical appendix. Finally owing to this unique price level of ψ^* given T^*, the rest of equilibrium objects must be unique as well. To assist the intuition graphically, supplementary figure 3 in the technical appendix also plots the aggregate regions of (a_h^*, a_f^*) in equilibrium. For notational convenience, these regions are henceforth referred to as "aggregate regions" as opposed to the "individual regions" described in Figure 2. Lastly, supplementary figure 4 in the technical appendix illustrates the flows of foreign assets between the two country in equilibrium.

5.2 Characterization of the Equilibrium

Given the existence of the equilibrium, the next task is to assess to what extent structural parameters of this economy, T^* and χ_h, affect the various steady state equilibrium objects. Lemma 5 confirms a unique equilibrium under $T^* < \breve{a} + c(\tilde{\kappa})/\beta$. This allows us to perform a comparative static analysis. Focusing on the unique equilibrium case, the Proposition 1 evaluates the effects of changes in T^* and χ_h on equilibrium prices and the equilibrium portfolio of (a_h^*, a_f^*).

Proposition 1. *The effects of foreign asset supply changes on the equilibrium are complicated. In fact, they critically depend upon the relative size of T^*. For instance, If $\breve{a} \leq T^* < \breve{a} + c(\tilde{\kappa})/\beta$, then, we have the following results: i) $\psi^* > \psi = \beta$ when $T^* = T$; ii) $\partial a_f^*/\partial T^* > 0$, $\partial a_h^*/\partial T^* > 0$, and $\partial \kappa/\partial T^* > 0$; and iii) $\partial \psi^*/\partial T^* < 0$. If on the other hand, $T^* < \breve{a}$, then, we have different results: i) $\psi^* > \psi > \beta$ when $T^* = T$; ii) $\partial a_f^*/\partial T^* > 0$ and $\partial \psi^*/\partial T^* < 0$; and iii) The signs of $\partial a_h^*/\partial T^*$ and $\partial \kappa/\partial T^*$ are ambiguous. The effects of a decline in search frictions within the FIM trade are, however, independent of T^* and straightforward as follows: i) $\partial a_h^*/\partial \chi_h > 0$; ii) $\partial a_f^*/\partial \chi_h < 0$; iii) $\partial \psi^*/\partial \chi_h > 0$; and iv) $\partial \kappa/\partial \chi_h > 0$.*

Proof. See technical appendix □

Proposition 1 reveals that the exogenous foreign asset supply drives the equilibrium in a non-trivial way. If assets are plentiful, in the precise sense that $\breve{a} \leq T^* < \breve{a} + c(\tilde{\kappa})/\beta$, then, the

during the FIM bargaining.

unique equilibrium must be reached within aggregate region 4, as shown in supplementary figure 3 of the technical appendix. It is already explained earlier why the foreign asset carries a liquidity premium in this region. Interestingly, under $T^* = T$, the home asset does have a liquidity premium since H always acquires $\tilde{q}$ in this equilibrium region. What is more important is the effect of a change in T^* on the equilibrium composition of (a_h^*, a_f^*). Given that both H and F would desire more liquidity in this region, it is obvious that an increase in T^* would increase equilibrium a_h^* and a_f^* simultaneously. This would, in turn, relieve the liquidity shortage for all agents, and therefore, the new equilibrium price (or liquidity premium) of the foreign asset should decline.[22] Finally, the FIM trade volume (κ) would increase in this case because otherwise the optimality for the home agent would imply a decrease in ψ^* which is a contradiction: recall that $\psi^* - \beta = \chi_h \beta \{u'(\kappa)/c'(\kappa) - 1\}$ in region 4 from Lemma 6.

The properties of equilibrium responses towards a shift in the foreign asset supply are richer if the asset is relatively scarce, that is, if $T^* < \breve{a}$. In this scenario, the equilibrium must occur within region 6 of the supplementary figure 3 of the technical appendix. First, if $T^* = T$, then, both the home and foreign assets carry the liquidity premium. Yet, note that the foreign asset exhibits liquidity properties in the FIM and the foreign country's local DM simultaneously makes $\psi^* > \psi$ in equilibrium. Second, it is intuitive that an increase in T^* would for sure induce F to demand foreign assets more. As a result of more foreign asset holdings by F, her optimality must require lower the costs of carrying the foreign asset, and thus, lower ψ^* in the new equilibrium.

The equilibrium response of a_h^* and κ to an increase in T^* would, however, be inconclusive. This ambiguity can be intuitively understood with the assistance of the liquidity dependent participation constraint for F during the FIM trade. At first, the decline in ψ^*, that is the marginal cost of carrying the foreign asset, would initially generate upward pressure for H's foreign asset demand. However, as T^* rises, F *ex-ante* anticipates a greater amount of liquidity from FIM trade. This would make F become less desperate for the foreign asset during FIM bargaining. Eventually, less favorable FIM terms of trade would be expected by H, and the initial upward

[22] A recent work by Krishnamurthy and Vissing-Jorgensen (2012) also demonstrates that bond supply does positively affect bond yields in the case of U.S. T-bonds.

pressure to hold more a_h^* would be somewhat mitigated. Therefore, the signs of Δa_h^* and $\Delta\kappa$ depend upon which of the two effects dominates, which in turn, is affected by the structural parameters of the economy.[23]

The most novel results of this study, discussed in Proposition 1, concern the effects of global financial integration on asset (bond) prices and the global portfolio composition. In essence, the extent to which OTC international investment markets are accessible to foreign agents is suggested as a key driving force behind the recent upsurge in emerging markets' international reserve holdings. The underlying intuition is straightforward. An increase in χ_h or a decrease in the search frictions in the FIM would first make the probability of matching in the FIM increase. This would undoubtedly raise the marginal benefit from holding foreign assets for home agents. Consequently, foreign asset holdings by the home country would rise, thus, $\partial a_h^*/\partial\chi_h > 0$.

The increase in χ_h also yields a clear implication on the global portfolio composition. While a_h^* rises in response to an increase in χ_h, a_f^* would instead decrease, that is $\partial a_f^*/\partial\chi_h < 0$. This is again attributed to foreign agents' fixed identity as a seller in the FIM trade (they would never use foreign assets as a medium of exchange for purchasing purpose during the FIM trade). As a result, the global portfolio of (a_h^*, a_f^*) would be increasingly biased towards a_h^* as χ_h (a proxy for the home country's financial openness) increases.

A higher χ_h would increase the higher liquidity properties of foreign assets through two channels. For one thing, the higher matching probability would surely make the liquidity value of foreign assets in the FIM higher. Further, the decline in the amount of a_f^* would cause foreign agents to *ex-ante* appreciate the liquidity property of the asset in their local DM more. To put it differently, since the higher χ_h effectively causes some of their foreign asset holdings to be transferred to home agents during the CM, foreign agents would *ex-ante* fear the liquidity loss within the subsequent local DM. In short, the higher χ_h gets, the higher agents appreciate the

[23] Nevertheless, it should be clear that the extent to which a_h^* increases in response to a rise in T^*, if true under some parameter values, must be smaller in aggregate region 6 than in 4. Technical details can be found in the technical appendix. Intuitively, this fact is attributed to the additional incentive change for F explained earlier. In fact, this less degree of positive relationship between T^* and a_h^* in aggregate 6 is a mirror image of the kinked foreign asset demand curve, $(D_h^*)^2$ in Supplementary Figure 2 in the technical appendix. It illustrates how H's demand exhibits lower price elasticity in region 6 than in 4. Since ψ^* and T^* have a negative one-to-one relationship in equilibrium, the less responsiveness of a_h^* to T^* in aggregate region 6 is obvious.

liquidity property of foreign assets in both FIM and the foreign country's local DM. This would eventually reduce (raise) the foreign asset's yield (price) at the new equilibrium: $\partial\psi^*/\partial\chi_h > 0$.

Finally, easier access to the OTC international investment markets also has a straightforward implication for the FIM trade volume. The increase in χ_h raises the FIM trade volume (κ) through the extensive margin (more matches between H and F). On top of that, the FIM trade volume would also rise through the intensive margin (within each match a larger amount of κ is produced, because the increase in χ_h induces home agents to carry more foreign assets). Naturally, a positive relationship between κ and χ_h should prevail in equilibrium: $\partial\kappa/\partial\chi_h > 0$.

6 Predictions of the Model and Empirical Evidence

The goal of this section is to empirically show that our model's predictions hold true with real data. To this end, we investigate if Proposition 1 in Section 5.2 is supported by the data. The main prediction of Proposition 1 is as follows: an increase in financial openness, χ_h, enhances the liquidity properties of foreign assets in FIM trade. Consequently, the relative share of the T^* (i.e. international reserves) by the home country rises, which also boosts the amount of foreign investment inflows, especially through OTC markets. Hence, the level of foreign asset stocks held by the home country and the OTC-channeled foreign investment inflows must be positively linked.

Note that apart from the main prediction above, Proposition 1 includes a richer set of comparative static analyses, especially regarding the effect of U.S. T-bond supply on bond prices and asset portfolio choices. Although these predictions are worth testing, we chose to rule them out for the following reasons. First, Krishnamurthy and Vissing-Jorgensen (2012) already confirm that supply changes of U.S. T-bonds have large (negative) price effects on U.S. T-bonds, and they attribute these effects to the superb liquidity properties of U.S. T-bonds. With regard to the relationship between the supply of U.S. T-bonds and reserve hoarding, our model prediction is ambiguous, and depends on the threshold of the treasury securities supply. An empirical investigation for this threshold is non-trivial and certainly not within the scope of this study. Lastly, in a panel set up, estimating the heterogeneous responses of reserve hoarding to changes in U.S. T-bond supply would be restricted because the latter is a common shock to all emerging countries. Therefore, in what follows, we only focus on the relationship between OTC foreign capital inflows and international reserves. We first introduce our estimation strategies and then describe the data and how our main variables are constructed. Our empirical results follow in the last sub-section.

6.1 Empirical Specification

In our theoretical model, OTC inflows and reserves/GDP are all determined endogenously. Thus, we introduce the following system of equations (13) and (14) to analyze our Proposition 1, in the spirit of previous studies such as Imbs (2004), Davis (2014), and Pyun and An (2016).[24] This simultaneous equation model considers the endogeneity between key variables—OTC inflows and reserve holdings. Specifically, the model makes it possible to disentangle the simultaneous effects between two key variables, as well as to estimate the effects of financial openness on the two variables. Our simultaneous equation model consists of two equations:

$$R\_GDP_{i,t} = \alpha_0 + \alpha_1 \cdot OTC_{i,t} + \alpha_2 \cdot FO_{i,t} + X'_{i,t} \cdot \alpha_3 + \epsilon_{1i,t}, \tag{13}$$

$$OTC_{i,t} = \beta_0 + \beta_1 \cdot R\_GDP_{i,t} + \beta_2 \cdot FO_{i,t} + W'_{i,t} \cdot \beta_3 + \epsilon_{2i,t}. \tag{14}$$

Two endogenous variables are $R\_GDP_{i,t}$ and $OTC_{i,t}$. $R\_GDP_{i,t}$ is the ratio of official international reserve to GDP, and $OTC_{i,t}$ is a measure for OTC foreign capital inflows to an emerging country i, which is OTC flows divided by GDP. $FO_{i,t}$ is a measure for financial openness which triggers shocks in the system. Vectors $X'_{i,t}$ and $W'_{i,t}$ contain exogenous variables that affect reserves-to-GDP and OTC inflows, respectively. We will discuss exogenous variables that identify the coefficients of $R\_GDP_{i,t}$ and $OTC_{i,t}$ in detail in the following section. We also include country fixed effects, year fixed effects, and banking and currency crisis dummies as another set of exogenous variables outside of the system. Country fixed effects and year fixed effects address country and year specific unobserved characteristics. Hence, if the system is well identified, the simultaneous equations model can be used to isolate the effects of financial openness

[24] Imbs (2004), Davis (2014), and Pyun and An (2016) employ a simultaneous equation approach to identify the relationship among four endogeneous variables—financial integration, trade integration, industrial specialization, and business cycle comovement.

on two endogenous variables, which are implied by coefficients α_2 and β_2, as well as the effects of OTC inflows on reserve holdings, and *vice versa*, which are implied by α_1 and β_1.[25]

6.2 Data and Identification

Since OTC foreign capital inflows are a new variable in the literature, no other benchmark variables exist. Furthermore, to the best of our knowledge, no aggregate data on these flows are available for emerging economies. For this reason, we must rely on imputed measures for OTC flows. First, we exploit the stylized fact that most emerging market debts are traded in OTC markets (Duffie, Gârleanu, and Pedersen (2005)). As such, debt liability flows from International Financial Statistics (IFS) have been chosen as our basic proxy for OTC foreign capital inflows.

In addition, FDI inflows into emerging countries have increasingly been in the form of mergers and acquisitions (M&A) (especially in financial FDI activities), a substantial portion of which is transacted outside a centralized clearing house system (e.g., a stock exchange). Therefore, we add FDI liability flows to debt liability flows and divide it by GDP, for our baseline measure of OTC foreign capital inflows. We readily admit that this measure may suffer measurement errors, as the IFS does not offer segregated data on portfolio debt or FDI in terms of trading characteristics. However, we partially reduce measurement errors by controlling for country fixed effects.

To overcome any measurement errors of our baseline OTC measures, we also introduce venture capital inflows as a direct measure for OTC inflows. The rationale is straightforward. OTC transactions feature prominently in the venture capital (i.e. private equity) market, and there have been rapid increases in the size of the venture capital industry over the past two decades (see Silviera and Wright (2007), and references therein, for more information). In this market, there are two typical players: entrepreneurs with viable ideas for projects, and venture capitalists (i.e. private equity firms) who have expertise in evaluating and implementing those

[25] In the current study, we assume homogeneous slope coefficients on reserve holdings across countries. However, one may argue that countries have heterogeneous demand for reserves as a medium of exchange (MOE). For example, some countries may have a lesser/greater need for reserves for the acquisition of foreign capital because their own currency is more/less suited for MOE or because they already have abundant domestic liquidity. We save this important issue for future research.

potentially high-risk-high-return projects, as well as access to private equity funds. Typically, venture capitalists put forth a great deal of resources and time in searching for target firms or projects. Once the two players match, they bargain over terms of trade, another feature of OTC trade (e.g., see Kaplan and Stromberg (2001) and Silviera and Wright (2007) for a more detailed explanation on the OTC aspects of venture capital investment).

Data for the venture capital inflows are sourced from the FactSet database. The FactSet database provides useful information on global equity ownership for about 13,000 institutions and 33,000 funds. Many financial institutions, including mutual funds, pension funds, bank trusts, and insurance companies, are required to frequently disclose their asset holdings to the public. The FactSet is able to gather data on these asset holdings from various sources.[26] A nice feature of the FactSet database is that it provides information on the market value of institutional holdings by institution type, institution domicile, and the final destination of the institutional investment. FactSet classifies individual institutional entities into 27 broad institutional types—investment advisor, hedge fund manager, venture captial/private equity, etc. Here, we focus on a specific entity of investors, venture capital/private equity. In particular, FactSet data classify private equity as institutions that invest almost exclusively in private equity, which are most often venture capital firms. These institutions are looking to reap large profits from companies through a merger or sale, an initial public offering, or a recapitalization, all of which carry more risk than a typical investment. We retrieve holdings of these institutions classified as venture capital/private equity and aggregate them by host country. Unbalanced panel information on venture capital investment (gross) inflows for 23 host countries during 1999-2011 is compiled. However, data coverage is limited (only 159 observations are available).

$X'_{i,t}$ and $W'_{i,t}$ contain exogenous variables to help to describe the relationship between $R\_GDP_{i,t}$ and $OTC_{i,t}$. A common set of exogenous variables included in $X'_{i,t}$ and $W'_{i,t}$ is trade openness

[26] For equities traded in the United States, the FactSet collects institutional holdings by reviewing the mandatory quarterly 13F filings with the Securities and Exchange Commission (SEC) or by rolling up the holdings by individual mutual funds (N-30D filings with the SEC) managed by a particular fund management company. For equities traded outside the United States, it collects ownership data directly from sources such as national regulatory agencies or stock exchange announcements (e.g., the Regulatory News Service in the United Kingdom), local and offshore mutual funds, mutual fund industry directories (e.g., European Fund Industry Directory), and company proxies and annual reports. See Ferreira and Matos (2008) for more detailed information on the FactSet database.

(bilateral trade-to-GDP ratio), in addition to financial openness. For the identification of two equations (13) and (14), we use an exclusion restriction and add different set of exogenous variables in $X'_{i,t}$ and $W'_{i,t}$. First, $X'_{i,t}$ contains variables widely accepted in the literature (e.g., Aizenman and Lee (2007), Aizenman, Cheung, and Ito (2015), Cheung and Ito (2009), Obstfeld, Shambaugh, and Taylor (2010) and Steiner (2011, 2013)). These regressors are population (in billions), M2/GDP, exchange rate volatility (annual standard deviation of monthly exchange rate changes), terms of trade, total external debt (divided by GDP), short-term external debt (divided by GDP) and pegs (peg/soft-peg) dummies from Shambaugh (2004). Second, $W'_{i,t}$ contains GDP per capita (in thousands), which is a proxy for a country's quality of financial institutions, additionally for the identification of equation (13). Finally, banking and currency crisis dummies from Laeven and Valencia (2012) are introduced as an additional exogenous variables.

Data is collected from World Development Indicators (WDI), the World Bank, International Financial Statistics (IFS), the IMF. Data on $defacto$ and $dejure$ financial openness are sourced from Lane and Milesi-Ferretti (2007b), and Chinn and Ito (2008) respectively. Observations from 71 emerging and developing countries (including developed countries such as Korea and Singapore with substantial reserve holdings) for the years 1990-2011 are arranged in an unbalanced panel dataset. Table 1 reports the descriptive statistics. The sample countries are listed in supplementary table 1 of the technical appendix.

6.3 Empirical Results

6.3.1 Main Results

Tables 2 and 3 present the results from the system of equations (13) and (14), which are estimated using a three-stage-least-squares (3SLS) analysis. Bootstrap standard errors are also reported in parenthesis. Table 2 contains only the main variables of interest, OTC inflows (=debt liabilities + FDI liabilities/GDP), reserve holdings (=Reserves/GDP), and financial openness. We isolate the effects of OTC inflows on reserves/GDP, and *vice versa*, by introducing a financial openness variable. Column (1) reports the results for the first model, in which the financial openness measure is included as an exogeneous variable only for the OTC inflows equation. The estimated coefficient of OTC inflows on reserve accumulation is positive and significant at the 1% level. The lower panel of column (1) shows that the estimated coefficient of reserves-to-GDP is significant and positive at the 1% level. The coefficient of financial openness is significant and positive as well. These three coefficients in column (1) confirm the theoretical prediction that a higher degree of financial openness in the FIM would lead to a higher level of foreign asset holdings by the home country.

In column (2), we instead include the financial openness variable only for the reserves equation. The estimated results in column (2) are consistent with those in column (1), and reaffirm the positive relationship between OTC inflows and international reserve holdings. Columns (3) and (4) iterate the same specifications in columns (1) and (2) with the alternative OTC measure, that is, venture capital inflows provided by FactSet database. Owing to limited data, the number of observations shrinks from 1519 to 160, but the results support our main message: the estimated coefficients on the OTC inflows and the reserves are positive and significant in columns (3) and (4) respectively although the estimated coefficient of financial openness on venture capital in column (3) becomes statistically insignificant. Note that for the results with direct OTC measure of venture capital flows, we report standard errors without bootstrapping owing to small sample size of less than 500. Although the non-parametric bootstrap method does not require any strong assumptions regarding the distribution of the statistic, a reasonable bootstrap requires a sufficient sample size of at least 500 (with 100 independent clusters), which satisfies a key assumption of the similarity between the characteristics of the sample and of the population (Guan (2003)). The results in Table 2 that contain key variables derived from the model strongly support Proposition 1. However, these results might be biased because other controls that affect OTC inflows and reserve holdings are not fully included in the system.

Table 3 shows the main results of this study. Here, other exogenous variables for OTC inflows and reserves-to-GDP are added to check the robustness of the results in Table 2. The results in Table 3 are consistent with those in Table 2. In columns (1)-(3), we include the financial openness variable, which is considered as an exogeneous shock in the model in both

OTC inflows and reserves equations (column (1)), and each equation (columns (2) and (3)). The upper and lower panels in column (1) show the results of the simultaneous regression equations for OTC inflows and reserve accumulation, respectively. The estimated coefficients on reserves-to-GDP and OTC inflows are positive. In particular, OTC inflows had a positive effect on reserve accumulation significantly at the 5% level. The coefficients on financial openness are positive in both the upper and the lower panels even though only the coefficient on financial openness in the OTC inflows equation is statistically significant. In columns (2) and (3), we control for financial openness in either of the two equations. Not only is the positive relationship between OTC inflows and reserves-to-GDP preserved in columns (2) and (3) but financial openness also has a positive impact on OTC inflows significantly.

To understand economic significance of our results, we quantify the effect of OTC inflows on reserve accumulation. In column (3) of our main Table 3, an increase in OTC flows-to-GDP by one standard deviation (or 0.059) increases reserves-to-GDP by 0.0295 percetage points. This increase is equivalent to 17 percent from the mean of reserves-to-GDP. Furthermore, to improve our understanding of the role of OTC flows, we trace changes in OTC inflows-to-GDP and reserves-to-GDP from 2000 to 2007, right before the global financial crisis. During this period, OTC inflows-to-GDP had increased from 0.37 to 0.86 on average and reserves-to-GDP had increased from 0.143 to 0.231. Our empirical results in Table 3 suggest that this increase in OTC inflows-to-GDP during the period results in an increase in reserves-to-GDP by 0.024, which accounts for 27.9 percent of total changes in reserves-to-GDP during this period.

Throughout columns (1)-(3), other explanatory variables have the expected signs for reserve holdings. For instance, M2/GDP, and trade openness have significant and positive impacts on reserve holdings, which is consistent with previous findings. Interestingly, two external debt variables—total and short-term external debt (stock) to GDP —that resemble OTC inflows have an insignificant effect on reserve holdings, while OTC inflows have significantly positive effects on reserve holdings. Again, our results strongly support a positive relationship between OTC inflows and reserve accumulation even controlling for other important controls such as external debt variables.

Table 4 introduces a direct measure for OTC inflows—namely, venture capital inflows. The results are consistent with main finding of Table 3. The estimated coefficients on OTC inflows and reserves in the system of equations are positive and statistically significant. Note that the estimated coefficient of financial openness on venture capital becomes negative (but insignificant), which is counter to the model's prediction. However, when excluding the financial openness measure from the reserves equation, the financial openness coefficient in column (3) turns out to be positive although it remains insignificant. This insignificant inference on financial openness may be caused by the small number of observations for venture capital inflows.

6.3.2 Robustness checks

Alternative hypotheses

To strengthen our theoretical arguments on the liquidity role of reserves, we include additional empirical tests to check the relationship between reserve holdings and two alternative notions of reserve asset liquidity–market liquidity and funding liquidity. Regarding the former, we choose to use a proxy used by Krishnamurthy and Vissing-Jorgensen (2012). It measures a Aaa-Treasury corporate bond spread (a long-maturity T-bond yield minus Moody's Aaa long-maturity bond index). The idea is that this difference extracts a superb liquidity property of T-bonds, i.e., the relative ease of trading it compared to Aaa corporate bonds with same safety attributes. As for the funding liquidity measure, we employ one of the most widely used measures, TED spread introduced by Amihud, Mendelson, and Pedersen (2013).

In addition to these two measures, we construct a third measure, portfolio equity inflows into emerging markets, for another robustness check. The essence of our liquidity-based mechanism is that OTC capital inflows effectively requires U.S. T-bonds as a MOE due to the OTC trading feature such as search-and-bargaining frictions. Yet, centralized capital inflows such as portfolio equity inflows can substantially bypass these frictions through a centralized clearing house, thereby weakening the need for a MOE. This implies that if reserve holdings turn out to be unrelated to portfolio equity inflows, but related to OTC inflows instead, our liquidity-based explanation could be further strengthened.

Applying these three measures into the simultaneous equations model, we have re-tested our main hypothesis in Table 5. Results reported in Table 5 are very supportive of our main story. Positive effects of OTC inflows on reserve accumulation remain valid even after including alternative liquidity variables and centralized capital flows as additional regressors. However, the estimated coefficients on market liquidity, funding liquidity, and centralized inflows all turn out be insignificant. Eventually, the results in Table 5 can distinguish our notion of liquidity from others and casts a strong support for our specific interpretation of the reserve asset liquidity.

Alternative specification: Panel vectorautoregressions (Panel VAR)

In this sub-section, we adopt a panel VAR model to allow for the dynamic interactions between OTC inflows and reserve holdings. We assume that an individual economy $i \in \{1, 2, ..., 71\}$ is described by the following structural form equation:

$$A(L)Y_{it} = e_{it}, \tag{15}$$

where $Y'_{it} = (FO_{it}, OTC_{it}, R\_GDP_{it})$ is a 1×3 vector, $A(L)$ is a matrix polynomial in the lag operator L, and e_{it} denotes a 3×1 vector of structural disturbances. By assuming that structural disturbances are mutually uncorrelated, $var(e_{it})$ is denoted by Δ, a diagonal matrix of which diagonal elements are the variances of structural disturbances. We pool the data and estimate the following reduced-form panel VAR:

$$Y_{it} = B(L)Y_{i,t-1} + \mu_{it}, \tag{16}$$

where $B(L)$ is a matrix polynomial in the lag operator L, and $var(\mu_{it})$ is denoted by Σ. There are several methods of recovering the parameters in the structural form equation from the estimated parameters in the reduced form equation. In our regression, the ordering of variables in the vector Y_{it} implies that R_GDP_{it} is able to react to the contemporary shocks from the other two variables, but does not affect them contemporaneously. In other words, we rely on simple identification schemes which impose recursive zero restrictions on contemporaneous structural parameters by applying the Cholesky decomposition. Let A_0 be the contemporaneous coefficient matrix in the structural form in eq.(15), and let $A^0(L)$ be the coefficient matrix in $A(L)$ without the contemporaneous A_0. Then, $A(L) = A_0 + A^0(L)$, which implies that the $B(L)$ in the reduced form is related by $B(L) = -A_0^{-1}A^0(L)$. In addition, the variance of the structural disturbances and that of the residuals of the reduced form are related using $\Sigma = A_0^{-1\prime} \Delta A_0^{-1}$.

To determine the optimal number of lags in system (15), we conduct a number of specification tests. As is often the case, the optimal number of lags varies greatly across country-groups and tests. We include a year lagged variable in all reported results. It is reassuring that all of our results are robust to choosing any alternative number of lags from 1 to 3.

Figure 3: Impulse-response functions

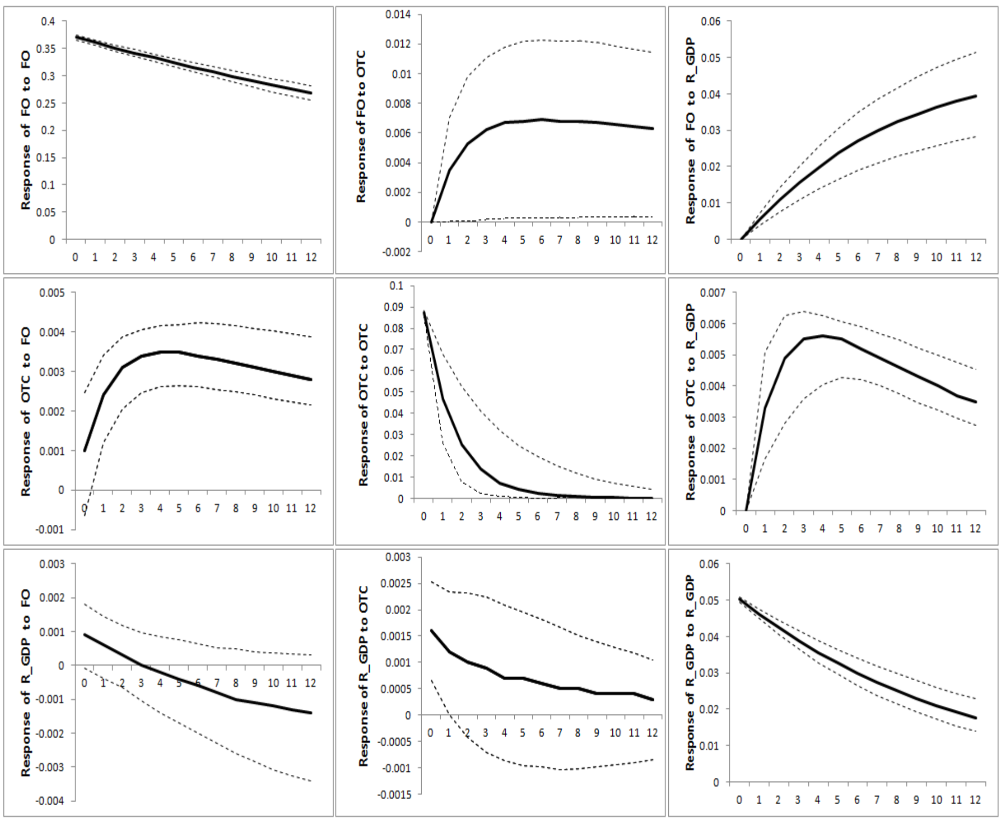


Figure 3 shows the impulse-response functions. We compute standard errors of the impulse response functions and generate 90% confidence intervals with Monte Carlo simulations having 1000 repetitions. In practice, we randomly generate a draw of coefficients of the reduced form model in eq.(16) using the estimated coefficients and their variance-covariance matrix. We then calculate the impulse-responses again.

First, our main interest in the Figure 3 is the responses of reserves-to-GDP to a 1-standard-deviation shock in OTC inflows-to-GDP in the third row and the second column. The responses of reserves-to-GDP to OTC inflows-to-GDP are positive over all periods. In particular, the impact response of reserves-to-GDP is significant and positive but became statistically insignificant at the 90% confidence interval from the second quarter. At the second row of Figure 3, the responses of OTC inflows-to-GDP to financial openness and reserves-to-GDP are included. OTC inflows increase significantly in response to a positive shock on financial openness. A positive feedback of OTC flows to reserve holdings is also observed. Overall, panel VAR results that allow for dynamic interactions between OTC flows and reserve accumulation are consistent with our main findings in the simultaneous equation model.

Alternative measures

To check further robustness of the results, we implement our main simultaneous equations with alternative measures for OTC inflows and financial openness. First we employ the $de facto$ financial openness measure instead of the $dejure$ financial openness measure in our baseline specifications in Table 3. We also consider debt liabilities only as a proxy for OTC inflows. All the results in supplementary tables 2 and 3 of technical appendix support the model's prediction consistently.

7 Concluding Remarks

We argue that factoring in OTC features of international capital markets might be a key to understanding emerging economies' reserve accumulation over the last decade. Since these decentralized markets lack perfect credit and commitment, a facilitator of trade, that is, a liquid asset, is required. Typically, U.S. T-bonds have served this role, either through collateral or buffer stocks against the repatriation of foreign capital. Declining financial frictions in these markets thus enhance the assets' liquidity property, which induces developing counties in need of sustained foreign investment to acquire U.S. T-bonds relatively more. As a result, the amount of emerging economies' U.S. T-bonds holdings would rise in equilibrium. Furthermore, the sustained increase in the U.S. T-bonds' liquidity attribute leads to a higher liquidity premium on these assets, thereby causing low real U.S. interest rates. Indeed, our simultaneous equations estimation approach, controlling for the endogenous relationship between OTC inflows and reserve holdings lends strong support for this liquidity-based story.

Policy implications from our study are two-fold. First, our findings stress that OTC foreign capital inflows are potentially a very important, but largely neglected so far in the literature, determinant and/even or predictor of international reserves. As such, taking OTC inflows seriously might be of particular importance to those who are interested in the adequacy of international reserves forecasting.

Second and more importantly, our findings may be of practical importance to policy makers who are concerned about the appropriate level of international reserves. Conventional wisdom has it that the optimal level of reserves should be critically dependent upon the probability of sudden stops and/or the degree to which policy makers aim for the export competitiveness. Here, we add a third dimension. The optimal level of reserves should also be conditional on the degree to which international capital markets are decentralized or search frictions prevail in those markets. Our study goes so far as to argue that the optimal level of reserves should qualitatively move in the same direction as the degree of decentralization within OTC international capital markets. Of course, one should really not think of 'search frictions' as physical frictions between foreign investors and local recipients in this case. In fact, they are meant to capture a broader notion of frictions such as financial regulations and capital controls imposed by emerging economies.

Last but not least, the aim of our argument for alternative understanding of reserve accumulation is not to refute existing explanations. Instead, one should view this paper's alternative explanation as complementary to existing ones. We also hope that our complementary view can enrich the literature. For example, one can further look into a joint relationship between internationalization of emerging market currencies, the optimal degree of decentralization in OTC international capital markets, and the optimal level of international reserves. Our study can provide a benchmark for this very important yet ambitious analysis.

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Table 1: **Summary Statistics**

Variables	**Obs.**	**Mean**	**Std. Dev**	**Min.**	**Median**	**Max.**
Reserves/GDP	1519	0.167	0.159	0.000	0.130	1.195
OTC inflows(Debt+FDI) (divided by GDP)	1519	0.045	0.059	-0.260	0.031	0.560
OTC inflows(Debt only) (divided by GDP)	1519	0.040	0.054	-0.164	0.026	0.541
Venture capital (X100) (divided by GDP)	149	0.108	0.410	0.000	0.011	4.110
Financial openness ($dejure$)	1432	0.303	1.477	-1.875	0.053	2.422
Financial openness ($defacto$)	1519	1.886	3.360	0.091	1.127	29.370
Trade openness (Export plus Import to GDP)	1473	0.875	0.578	0.003	0.764	4.468
GDP per capita (in thousands)	1417	10.640	12.029	0.691	6.682	96.262
Population (in billions)	1483	0.062	0.195	0.0005	0.010	1.344
M2/GDP	1448	0.494	0.373	0.055	0.409	3.236
Terms of trade	1490	104.369	25.814	46.6	100	259.514
Total external debt (divided by GDP)	1094	0.557	0.715	0.030	0.452	20.837
Short-term external debt (divided by GDP)	1094	0.08	0.163	0	0.051	4.695
Exchange rate volatility	1446	0.026	0.079	0	0.013	1.944
Pegs (Peg/Soft peg)	1519	0.616	0.486	0	1	1
Currency crisis	1519	0.028	0.164	0	0	1
Banking crisis	1519	0.099	0.298	0	0	1

Table 2: **OTC Inflows and Reserves/GDP**

	Simultaneous Equations Model (3SLS)			
	(1)	(2)	(3)	(4)
Dependent Var.		Reserves/GDP		
OTC or Venture Capital Inflows	2.7264***	2.2591***	0.9051***	0.1912***
	(0.2665)	(0.2807)	(0.0830)	(0.0594)
Financial Openness		0.0081***		0.0379***
		(0.0025)		(0.0023)
Dependent Var.	OTC Inflows	OTC Inflows	Venture Capital Inflows	Venture Capital Inflows
Reserves/GDP	0.2629***	0.2835***	0.9032***	0.6047***
	(0.0184)	(0.0199)	(0.1416)	(0.1049)
Financial Openness	0.0017***		0.0032	
	(0.0006)		(0.0023)	
Observations	1,519	1,519	160	160

Bootstrap standard errors are in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$
Country fixed effects, year fixed effects and currency and banking crisis dummies are included as exogneous variables in the system. We report standard errors without bootstrapping in columns (3) and (4) because of the small sample size of less than 500 (Guan, 2003).

Table 3: **Main results, A Full System of Equations**

Simultaneous Equations Model (3SLS)			
	(1)	(2)	(3)
Dependent var.		Reserves/GDP	
OTC Inflows	0.4707**	0.4748**	0.5013**
	(0.2123)	(0.2119)	(0.2126)
Financial Openness	0.0013	0.0023	
	(0.0021)	(0.0020)	
Trade Openness	0.0341***	0.0334***	0.0334***
	(0.0111)	(0.0113)	(0.0110)
POP	-0.0520***	-0.0518***	-0.0533***
	(0.0149)	(0.0149)	(0.0146)
M2/GDP	0.2322***	0.2317***	0.2318***
	(0.0131)	(0.0132)	(0.0133)
TOT	0.0010***	0.0010***	0.0010***
	(0.0001)	(0.0001)	(0.0001)
Total External Debt/GDP	-0.0054	-0.0052	-0.0056
	(0.0096)	(0.0096)	(0.0096)
Short-term external Debt/GDP	0.0448	0.0440	0.0463
	(0.0339)	(0.0340)	(0.0333)
Exchange rate_volatility	-0.0430	-0.0431	-0.0447
	(0.0343)	(0.0344)	(0.0346)
Pegs	-0.0083*	-0.0082	-0.0079
	(0.0050)	(0.0050)	(0.0052)
R^2	0.497	0.497	0.494
Dependent var.		OTC Inflows	
Reserves/GDP	0.0589	0.0634*	0.0626*
	(0.0359)	(0.0373)	(0.0364)
Financial Openness	0.0046***		0.0047***
	(0.0011)		(0.0011)
Trade openness	0.0271***	0.0292***	0.0268***
	(0.0061)	(0.0064)	(0.0061)
GDPPC	0.0021***	0.0023***	0.0021***
	(0.0007)	(0.0007)	(0.0007)
R^2	0.142	0.129	0.141
Observations	970	970	970

Bootstrap standard errors are in parentheses.*** p<0.01, ** p<0.05, * p<0.1
Country fixed effects, year fixed effects, and currency and banking crisis dummies are included as exogneous variables in the system

Table 4: **Direct OTC measure, Venture capital**

	Simultaneous Equations Model (3SLS)		
	(1)	(2)	(3)
Dependent var.		Reserves/GDP	
Venture Capital Inflows	0.0835***	0.0843***	0.0934***
	(0.0275)	(0.0274)	(0.0276)
Financial Openness	0.0084*	0.0081*	
	(0.0047)	(0.0046)	
Trade Openness	0.1115***	0.1133***	0.1484***
	(0.0250)	(0.0246)	(0.0150)
GDPPC	0.0041***	0.0041***	0.0042***
	(0.0012)	(0.0012)	(0.0012)
POP	0.1194***	0.1194***	0.1217***
	(0.0216)	(0.0216)	(0.0218)
M2/GDP	0.0528***	0.0529***	0.0606***
	(0.0166)	(0.0166)	(0.0161)
TOT	0.0004*	0.0004*	0.0005**
	(0.0002)	(0.0002)	(0.0002)
Exchange rate_volatility	-0.4812	-0.4815	-0.5073
	(0.4328)	(0.4324)	(0.4374)
Pegs	0.0183	0.0183	0.0135
	(0.0189)	(0.0189)	(0.0190)
R^2	0.916	0.916	0.912
Dependent var.		OTC Inflows: Private Venture Capital	
Reserves/GDP	1.0760***	1.0523***	1.0817***
	(0.3335)	(0.3195)	(0.3325)
Financial Openness	-0.0070		0.0017
	(0.0212)		(0.0206)
Trade Openness	-0.3028***	-0.3304***	-0.3437***
	(0.1127)	(0.0801)	(0.1106)
GDPPC	0.0196***	0.0195***	0.0194***
	(0.0042)	(0.0042)	(0.0042)
R^2	0.198	0.200	0.197
Observations	140	140	140

Standard errors are in parentheses.*** p<0.01, ** p<0.05, * p<0.1
We do not use bootstrapping owing to small sample size of less than 500 (Guan, 2003)
Country fixed effects, year fixed effects, and currency and banking crisis dummies are included as exogneous variables in the system.
External debt variables are omitted because when including the debt-variables, the number of observations shrinks to 75.

Table 5: **Alternative hypotheses**

	Simultaneous Equations Model (3SLS)			
	(1)	(2)	(3)	(4)
Dependent var.		Reserves/GDP		
OTC Inflows	0.5440***	0.4921**	0.4009*	
	(0.1579)	(0.2192)	(0.2245)	
Market Liquidity	0.0033			
(Aaa-Treasury spread)	(0.0058)			
Funding Liquidity		-0.0105		
(Ted spread)		(0.0116)		
Centralized Inflows			2.1871	1.3223
			(2.7535)	(7.8943)
Financial Openness	0.0010	0.0012	-0.0008	0.0025
	(0.0024)	(0.0021)	(0.0033)	(0.0029)
Trade Openness	0.0361***	0.0337***	0.0372**	0.0532***
	(0.0091)	(0.0112)	(0.0150)	(0.0139)
POP	-0.0430***	-0.0515***	-0.0131	-0.0125
	(0.0132)	(0.0149)	(0.0166)	(0.0190)
M2/GDP	0.1982***	0.2316***	0.1724***	0.1761***
	(0.0116)	(0.0132)	(0.0143)	(0.0143)
TOT	0.0010***	0.0010***	0.0008**	0.0009***
	(0.0004)	(0.0003)	(0.0003)	(0.0003)
Total External Debt/GDP	0.0017	-0.0057	0.0153	0.0080
	(0.0091)	(0.0096)	(0.0198)	(0.0227)
Short-term External-	0.0135	0.0456	0.2906***	0.3064***
Debt/GDP	(0.0424)	(0.0343)	(0.0654)	(0.0669)
Exchange rate_volatility	-0.0310	-0.0402	-0.0432	-0.0932
	(0.0278)	(0.0325)	(0.1530)	(0.1333)
Pegs	-0.0009	-0.0085*	0.0080	0.0022
	(0.0049)	(0.0050)	(0.0077)	(0.0093)
R^2	0.516	0.496	0.635	0.633
Dependent var.		OTC Inflows :Debt liability only		Centralized flows :Equity flows
Reserves/GDP	0.0837**	0.0603*	0.0913	0.0003
	(0.0424)	(0.0357)	(0.0583)	(0.0017)
Financial Openness	0.0039***	0.0046***	0.0061***	-0.0001
	(0.0013)	(0.0011)	(0.0020)	(0.0001)
Trade Openness	0.0220***	0.0270***	0.0154	0.0001
	(0.0062)	(0.0061)	(0.0099)	(0.0003)
GDPPC	0.0033***	0.0021***	0.0039***	0.0001***
	(0.0008)	(0.0007)	(0.0012)	(0.0000)
R^2	0.169	0.142	0.260	0.066
Observations	825	970	350	357

Bootstrap standard errors are in parentheses.*** p<0.01, ** p<0.05, * p<0.1
Country fixed effects, year fixed effects, and currency and banking crisis dummies are included as exogneous variables in the system.