International Reserves for Emerging Economies: A Liquidity Approach.

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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 propose that a dynamic general equilibrium model incorporating international capital markets, characterized by a non-centralized trading mechanism and U.S. T-Bonds as facilitators of trade, can provide an answer to this question. Declining financial frictions in these over-the-counter (OTC) markets would generate rising liquidity premiums on U.S. T-Bonds. Meanwhile, the higher 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 reserves holdings.

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

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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]

While 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 on reserve determinants.[2] Yet, these studies mainly focus on *empirical* tests for new determinants. Far fewer have suggested *general equilibrium* models of reserve determination. Thus, while progress on solving the puzzle has been made, a fully-fledged analysis on the equilibrium relationship between reserve accumulation, interest rates, and net foreign asset positions remains to be done.

To that end, we construct a two-country dynamic general equilibrium (DGE) model of reserve determination. We use this framework to study how the three aforementioned variables 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. Our model is novel, not just because it takes a DGE approach, but because it considers a very important yet largely neglected attribute of the reserve assets, *liquidity*.[3] Dooley, Folkerts-Landau, and Garber (2004) argue that reserve assets could facilitate foreign capital inflows into emerging markets by serving as aggregate collateral. Moreover, reserve assets could also alleviate the loss from the repatriation of foreign capital by serving as a means of buying them back (see Aizenman and Marion (2004)). What is of importance is that despite these different roles, reserve assets could *effectively* serve as a medium of exchange for emerging economies, as holding more of these assets would enhance foreign capital inflows.

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

[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); and Obstfeld, Shambaugh, and Taylor (2010).

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

[3] A recent empirical study by Krishnamurthy and Vissing-Jorgensen (2012) demonstrates that U.S. Treasury bonds have superb liquidity that is akin to the U.S. dollar.

asset pricing model for which assets, in addition to the discounted value of future dividend streams, can be valued for their endogenous liquidity properties.[4] We take this insight further and apply it to a global portfolio choice problem with endogenous changes in reserve assets' liquidity property.

The main result of our model is straightforward. The sustained enhancement of reserve assets' liquidity may hold the key to understanding the recent upward trend in reserve accumulation by many emerging economies. The explanation for the endogenous and simultaneous change in reserve assets' liquidity as well as reserve hoarding is as follows. 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 for the acquisition of foreign capital.[5] Consistent with empirical evidence, our model also assumes that only the reserve asset, that is U.S. T-Bonds, is accepted as a means of payment within international capital markets.[6]

Within this framework, reserve assets 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.[7]

[4] With *ad hoc* assumptions, such as a cash-in-advance constraint, accounting for endogenous change in asset liquidity is virtually impossible. This is where the monetary search framework's usefulness comes in.

[5] 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 and Herrenbrueck (2013) 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.

[6] 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.

[7] We admit the importance of the role of emerging market's public sectors, i.e., central banks, in the emergence of rapid reserve accumulation. Nonetheless, analyzing the phenomena purely from the perspective of a private sector's portfolio choice is not implausible either. This is because most emerging economies are channeling their private sector's foreign asset savings through the official sector. In other words, the reserve assets held by the central bank in emerging economies are indirectly controlled by private sector decisions through capital controls, the issuance of quasi-collateralized sterilization bonds, and so on. See Caballero, Farhi, and Gourinchas (2008) for more empirical observations that justify this approach.

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. Over the last decade, the global economy has 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).

To further justify the model framework, as well as associated predictions, we conduct a quantitative empirical analysis. First, we construct various measures for aggregate OTC inflows for a collection of 71 emerging and developing economies using data from 1990 to 2011. For the measure based on venture capital inflows, we use new data collected from the FactSet database.[8] Then, we inspect the relationship between OTC inflows and various other macro variables in accordance with our theoretical predictions. Figure 1 demonstrates good heuristic empirical support for our model framework and predictions, showing a rapidly increasing trend for aggregate OTC inflows. More interestingly, the trend exhibits a close connection with the upward trend for reserve accumulation.

For a more rigorous econometric analysis, we set up a testable hypothesis of the model 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 between the two key variables (implied by the model), we adopt a simultaneous equations estimation approach, following Imbs (2004). Through various econometric specifications and robustness checks, we find strong empirical support for our liquidity-based theory of international reserves 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 fiasco. By restricting the two-country model to a symmetric financial asset case in terms of pledgeability aspects, our model does not suffer

[8] Section 6 will explain in detail how different measures for OTC capital inflows are constructed.

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.[9] 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.

The studies of Cheung and Qian (2009) and Qian and Steiner (2014) are two most similar 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 equity investment (PEI), thereby altering the composition of foreign capital inflows between FDI and PEI. Our approach differs to these 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, e.g., Geromichalos, Licari, and Suarez-Lledo (2007); Lagos and Rocheteau (2008); Lagos (2011); Lester, Postlewaite, and Wright (2012); Zhang (2014). 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) also bring the monetary search literature closer to questions related to international portfolio diversification. Similarly to the present study, they consider a two-country environment characterized by assets' role as media of exchange, which plays a crucial role in rationalizing the home asset bias puzzle. Jung and Lee (2014) too 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

[9] 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.

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, while 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, I shall henceforth call 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. Yet, the agents can also choose to trade these goods for two different financial assets, i.e., 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 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.[10] 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.

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, which motivates H and F to trade with each other.[11] 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

[10] 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.

[11] Real world examples of capital goods could be foreign investment projects for building infrastructure, enhancing local firms' management skills and knowhow, developing financial market structure, and so on.

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.

Note also that, it is assumed that an exchange in the FIM requires a medium of exchange (MOE). Motivated by the theoretical arguments and empirical evidence given in footnotes 5 and 6, only foreign assets, that is U.S. T-Bonds, can serve as a direct medium of exchange. 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, 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), the local decentralized market is termed DM henceforth, and 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.[12] 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

$$\mathcal{U}^H(x, X, l, L, \kappa) = U(X) - L + u(\kappa) + u(x) - l,$$
$$\mathcal{U}^F(x, X, l, L, h) = U(X) - L - c(h) + u(x) - l.$$

Thus, the usual assumption for the utility and cost functions in the literature applies: $u' > 0, U' > 0, u'' < 0, U'' < 0, U'(0) = u'(0) = +\infty, c' > 0, c'' > 0$.[13]

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,

[12] 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.

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

respectively. This matching function, M, is assumed to be increasing 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

$$\chi_f = \frac{M(B,S)}{S} = M\left(\frac{B}{S}, 1\right) \equiv f(\theta),$$
$$\chi_h = \frac{M(B,S)}{B} = M\left(1, \frac{S}{B}\right) \equiv \theta\chi_f,$$

where θ is market tightness, and equals S/B. It is finally 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 $\sigma \leq 1/2$.[14] Last, σ is assumed to be symmetric across the two countries. Figure 2 summarizes the timing of the events in this model economy.

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

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

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

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, $W^H(a, a^*)$ is linear in state variables and therefore, 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.[15] 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[16]

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

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.

$$\Omega^H(a, a^*) = \chi_h \big\{u(\kappa) + V^H(a, a^* - b^*)\big\} + (1 - \chi_h) V^H(a, a^*), \tag{5}$$
$$\Omega^F(a^*) = \chi_f \big\{V^F(a^* + b^*) - c(\kappa)\big\} + (1 - \chi_f) V^F(a^*), \tag{6}$$

[15] 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.

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

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 line 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 line 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 line is the payoff from going to the next period's CM with no trade history in the current DM. F's value function in the DM can be computed in a similar way. Using the same intuition, the Bellman's equation for F can be expressed as

$$V^F(a^*) = \sigma \left\{ u(q(a^*)) + \beta W^F(a^* - n(a^*)) \right\} \tag{8}$$

$$+ \sigma \int \left\{ -q(\widetilde{a}^*) + \beta W^F(a^* + n(\widetilde{a}^*)) \right\} dF(\widetilde{a}^*) \tag{9}$$

$$+ (1 - 2\sigma)\beta W^F(a^*).$$

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

$$\begin{aligned} & \max_{\{q,n\}} \left\{ u(q) + \beta \left[W^H(a - n, a^*) - W^H(a, a^*) \right] \right\}, \\ & s.t. \;\; 1. \;\; q \le \beta \left[W^H(a + n, a^*) - W^H(a, a^*) \right], \\ & \qquad\; 2. \;\; n \le a. \end{aligned}$$

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

$$\max_{\{q,n\}} \{u(q) - \beta n\},$$
$$s.t. \;\; q = \beta n,$$

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 identically.

$$\max_{\{q^*,n^*\}} \left\{u(q^*) + \beta \left[W^F(a^* - n^*) - W^F(a^*)\right]\right\},$$
$$s.t. \;\; 1. \;\; q^* \leq \beta \left[W^F(a^* + n^*) - W^F(a^*)\right],$$
$$2. \;\; n^* \leq a^*.$$

The linearity of the $W^F(a^*)$ in e.q.(3) again simplifies the problem as

$$\max_{\{q^*,n^*\}} \{u(q^*) - \beta n^*\},$$
$$s.t. \;\; q^* = \beta n^*,$$

with the resource constraint, $n^* \leq a^*$. 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 $c(\tilde{\kappa}) < \beta\check{a} + \sigma\left[u(\tilde{q}) - \tilde{q}\right]$, the bargaining solution is as follows.[17]

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

Proof. See appendix □

Lemma 2 can be intuitively interpreted with an assistance of Figure 3 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 $\check{a}$. 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 3 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 ($\check{a}$) in the subsequent local DM. In this case,

[17] The other potential parameter space case where $\beta\check{a} + \sigma\left[u(\tilde{q}) - \tilde{q}\right] \le c(\tilde{\kappa})$ is relegated to 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.

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 3.

When the F's foreign asset holdings fall short of $\check{a}$ 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 $\check{a}$ (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 $b^* < a_h^*$.[18]

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.

[18] 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 $\tilde{\kappa}$

This would generate the following.

$$\begin{aligned}\Omega^H(\widehat{a}_h,\widehat{a}_h^*) = {} & \beta\widehat{a}_h^* + \chi_h\left[u(\kappa(\widehat{a}_h^*,\widehat{a}_f^*)) - \beta b^*(\widehat{a}_h^*,\widehat{a}_f^*)\right] \\ & + \beta\widehat{a}_h + \sigma\left[u(q(\widehat{a}_h)) - \beta n(\widehat{a}_h)\right] \\ & + \beta\Lambda^H + \sigma\int\left\{-q(\widetilde{a}) + \beta W^H(n(\widetilde{a}),0)\right\}dF(\widetilde{a}).\end{aligned} \tag{10}$$

The three lines 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 line corresponds to the 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 line 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. Last line 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.(10) 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.

$$\begin{aligned}J^H(\widehat{a}_h,\widehat{a}_h^*) = {} & [-\psi+\beta]\,\widehat{a}_h + [-\psi^*+\beta]\,\widehat{a}_h^* \\ & + \sigma\left[u(q(\widehat{a}_h)) - \beta n(\widehat{a}_h)\right] \\ & + \chi_h\left[u(\kappa(\widehat{a}_h^*,\widehat{a}_f^*)) - \beta b^*(\widehat{a}_h^*,\widehat{a}_f^*)\right].\end{aligned} \tag{11}$$

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.(11) is standard. The first line 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 line 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.(11) 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 3. This leads to different functional forms for the $J^H(\widehat{a}_h,\widehat{a}_h^*)$ with respect to the different regions. Lemma 3 presents an auxiliary result that highlights some important properties of the region specific $J^H(\widehat{a}_h,\widehat{a}_h^*)$.

Lemma 3. *Define $J_i^H(\widehat{a}_h,\widehat{a}_h^*), i = 1,\cdots,6$ as H's objective function in region i. Then the partial deriva-*

tive with respect to the second argument, $\widehat{a}_h^*$ in each region can be expressed as follows.

$$\frac{\partial J_1^H(\widehat{a}_h, \widehat{a}_h^*)}{\partial \widehat{a}_h^*} = \frac{\partial J_3^H(\widehat{a}_h, \widehat{a}_h^*)}{\partial \widehat{a}_h^*} = \frac{\partial J_5^H(\widehat{a}_h, \widehat{a}_h^*)}{\partial \widehat{a}_h^*} = -\psi^* + \beta,$$
$$\frac{\partial J_2^H(\widehat{a}_h, \widehat{a}_h^*)}{\partial \widehat{a}_h^*} = \frac{\partial J_4^H(\widehat{a}_h, \widehat{a}_h^*)}{\partial \widehat{a}_h^*} = -\psi^* + \beta + \chi_h \beta \left\{ \frac{u'(\kappa)}{c'(\kappa)} - 1 \right\},$$
$$\frac{\partial J_6^H(\widehat{a}_h, \widehat{a}_h^*)}{\partial \widehat{a}_h^*} = -\psi^* + \beta + \chi_h \beta \left\{ \frac{u'(\kappa)}{c'(\kappa)} \left[(1-\sigma) + \sigma u'(\beta(\widehat{a}_h^* + \widehat{a}_f^*)) \right] - 1 \right\}$$

Proof. See the appendix □

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

$$\begin{aligned}\Omega^F(\widehat{a}_f^*) = \beta \widehat{a}_f^* + \sigma \left[u(q(\widehat{a}_f^*)) - \beta n(\widehat{a}_f^*) \right] \\ + \beta \Lambda^F + \sigma \int \left\{ -q(\widetilde{a}^*) + \beta W^F(n(\widetilde{a}^*)) \right\} dF(\widetilde{a}^*).\end{aligned} \tag{12}$$

This expression can be interpreted in a similar manner to the e.q.(10). 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.(12) into e.q.(3) and focusing on the terms inside the maximum operator, one can derive the F's objective function as

$$J^F(\widehat{a}_f^*) = \left[-\psi^* + \beta \right] \widehat{a}_f^* + \sigma \left[u(q(\widehat{a}_f^*)) - \beta n(\widehat{a}_f^*) \right], \tag{13}$$

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.(11).

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.(11) and (13) are non-negative or not in equilibrium. The next lemma does this verification by stating important results regarding the sign of the cost terms in equilibrium.

Lemma 4. *In any equilibrium, the following two conditions must hold.*

$$\psi \geq \beta \quad \text{and} \quad \psi^* \geq \beta.$$

Proof. See appendix □

Notice that the β is the so-called *fundamental* asset value, i.e., the price that agents would be willing to pay for one unit of the asset if neither FIM nor DMs existed. The non-negative sign of the cost terms assigns a very intuitive meaning to the objective functions of agents. Agents wish to bring assets into either of the FIM and DM in order to facilitate trade. However, they face a trade-off because carrying these assets is not free, i.e., the first line in e.q.(11) and (13)). This eventually gives rise to the optimal portfolio choice problem of agents. 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 5. *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 appendix □

A standard marginal cost-benefit analysis can be applied to interpret the optimal condition in Lemma 5. 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 3. Thus, one ought to build on Lemma 3 in order to study the optimal behavior of H in details. Lemma 6 summarizes the results.

Lemma 6. *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 $\breve{a}$. On the other hand, if $\psi > \beta$ then, there exists an* ***unique*** *level of home asset holdings, $\widetilde{a}$ such that $\widetilde{a} \in (0, \breve{a})$ 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* $\psi^* - \beta = \chi_h \beta \{u'(\kappa)/c'(\kappa) - 1\}$.

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* $\psi^* - \beta = \chi_h \beta \{u'(\kappa)/c'(\kappa) - 1\}$.
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* $\overline{\psi^*} - \beta = \chi_h \beta \{u'(\kappa)/c'(\kappa) - 1\}$ *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 appendix □

Technical details of the H's optimization problem are relegated to appendix. In what follows, we provide intuitive interpretation of important properties of the H's optimal portfolio choice. First of all, her optimal home asset demand is trivial because she would only take the local DM's bargaining protocol into consideration. As a matter of fact, it is identical to the F's optimal foreign asset holdings since both H and F face a symmetric market structure in their own local DMs, i.e., same degree of search frictions prevail, and only local assets are used as media of exchange.

However, H's optimal choice for foreign asset holdings would be nontrivial. Suppose the foreign asset price is at the fundamental level ($\psi^* = \beta$) for instance. Since the cost of carrying foreign assets becomes zero, it would not be optimal for H to be in a region where her assets would not allow her to afford the optimal quantity of κ. In short, if $\psi^* = \beta$ then, H would never choose a portfolio in the interior of regions 2, 4 or 6 of Figure 3.

In contrast, if $\psi^* > \beta$, carrying the asset becomes costly. The optimal choice of H is then pinned down by the first-order conditions and, graphically, it lies within regions of either 2, 4 or 6 depending on her beliefs upon a_f^*. For instance, suppose H's belief on the F's foreign asset holdings happens to be greater than the first best liquidity amount ($\check{a}$). In this case, Lemma 3 confirms that the FOC associated with the region 2 always pins down the H's optimal choice of foreign asset holdings.

Interesting case happens when H believes that $\widehat{a}_f^*$ lies in between $\bar{a}_f^*$ and $\check{a}$. In this scenario, the relative size of the foreign asset price becomes crucial. When ψ^* is too high, i.e., $\psi^* > \overline{\psi^*}$, the cost of carrying asset becomes too burdensome for H. Thus, she would typically choose to hold less foreign assets and settle in the interior of region 6. Then, the associated FOC determines the optimal level of foreign asset holdings. On the other hand, if the ψ^* stays in a rather moderate range, i.e., $\beta < \psi^* < \overline{\psi^*}$, then, she would increase her foreign asset holdings so that her marginal benefit falls and equalizes to a new and diminished level of marginal cost, i.e., she would end up within the region 4.

To graphically sum up intuition, the foreign asset demand by H, D_h^* is plotted in Figure 4 against the price, ψ^*.[19] In this graph, H's belief on the level of F's foreign asset holdings is kept fixed at the values $(\widehat{a}_f^*)^1$, $(\widehat{a}_f^*)^2$ and $(\widehat{a}_f^*)^3$. These values are indicated in the lower panel of Figure 4, which replicates Figure 3. The vertical alignment of the two plots enables one to find which regions in terms of Figure 3 H finds herself in, for any choice of $\widehat{a}_h^*$, given the value of $(\widehat{a}_f^*)^j$, $j = 1, 2$ and 3. In essence, the greater F's foreign asset holdings are the more H demands the asset, i.e., $(D_h^*)^1 > (D_h^*)^2 > (D_h^*)^3$. This is because of the fact that F who holds more foreign assets becomes less desperate during the FIM trade. Thus, H would have to give up more foreign assets to induce F to accept the offer in the FIM bargaining.

Another important feature of the graph is the kinked demand curve for the moderate range of $\widehat{a}_f^*$, i.e., $(a_f^*)^2$. $(D_h^*)^2$ exhibits a kink at a threshold level of $\overline{\psi^*}$. To illustrate this property, one needs to recall the regime switch between region 4 and 6 in the neighborhood of $\overline{\psi^*}$ in the previous paragraph. Imagine a case where the foreign asset price steadily rises from its fundamental value β. Once the ψ^* pushes H from the region 4 into 6, she would deal with more desperate F during the FIM bargaining. This would in turn make her less sensitive to the change in the foreign asset prices compared to the case in the region 4. Another way of putting it is that F's willingness to provide more κ in exchange for the same amount of foreign assets would somewhat offset the effects of change in the cost of carrying assets. In short, H's elasticity of asset demand with respect to ψ^* should be lower in the region 6 than 4, consistent with the direction of a kink in $(D_h^*)^2$.

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.

[19] $a_{h,r}^*$ in Figure 4 is defined as follows. $a_{h,r}^* = \left\{ a_h^* : c(\tilde{\kappa}) = \sigma \left[u(q(a_f^* + a_h^*)) - u(q(a_f^*)) \right] + (1-\sigma)\beta a_h^* \right\}$.

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 (11) and (13)*
- ✓ *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 7. *If* $T^* < \breve{a} + c(\tilde{\kappa})/\beta$ *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 appendix □

Lemma 7 can be explained intuitively with Figure 3. If $T^* \geq \breve{a} + c(\tilde{\kappa})/\beta$, then the Figure 3 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

[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.

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 ($\breve{a}$) 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 $T^* < \breve{a} + c(\tilde{\kappa})/\beta$, it is understood from Figure 3 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 3, 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] 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 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, Figure 5 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 3.

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 7 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^*).

[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 during the FIM bargaining.

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 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 unique equilibrium must be reached within aggregate region 4, as shown in Figure 5. 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 $\psi^* - \beta = \chi_h \beta \left\{ u'(\kappa)/c'(\kappa) - 1 \right\}$ in region 4 from Lemma 3.

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 Figure 5. 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

[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.

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 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 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

[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 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 Figure 4. 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.

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 is supported in the data. The main prediction of Proposition 1 is clear: an increase in financial openness, χ_h, enhances the liquidity properties of foreign assets in the FIM trade. In consequence, the relative share of the T^* (international reserves) by the home country rises, which in turn 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, according to Proposition 1.

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-Bonds 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, as mentioned in footnote 3, Krishnamurthy and Vissing-Jorgensen (2012) already confirm that supply changes have large (negative) price effects on U.S. T-Bonds, and 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 reserves 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-Bonds supply would be greatly 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 important variables are constructed. Our empirical results follow in the last sub-section.

6.1 Empirical Specification

Throughout the empirical section of this paper, we estimate the following system of equations simultaneously, in the spirit of Imbs (2004), Davis (2014), and Pyun and An (2014). For instance, Imbs (2004) employs a simultaneous equation approach to identify the relationship among four endogeneous variables—financial integration, trade integration, industrial specialization, and business cycle comovement. In our empirical model, OTC inflows and Reserves/GDP are all determined endogenously. Thus, the simultaneous equations model that considers the endogeneity between key variables—OTC inflows and Reserves/GDP—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 equations model consists of two equations:

$$OTC_{i,t} = \alpha_0 + \alpha_1 \cdot R\_GDP_{i,t} + \alpha_2 \cdot FO_{i,t} + X'_{i,t} \cdot \alpha_3 + I'_{1i,t} \cdot \alpha_4 + \epsilon_{1i,t}, \quad (14)$$

$$R\_GDP_{i,t} = \beta_0 + \beta_1 \cdot OTC_{i,t} + \beta_2 \cdot FO_{i,t} + W'_{i,t} \cdot \beta_3 + I'_{2i,t} \cdot \beta_4 + \epsilon_{2i,t}. \quad (15)$$

Our 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. $FO_{i,t}$ is a measure for financial openness which triggers shocks in the system. Vectors $X'_{i,t}$ and $W'_{i,t}$ are other control variables that affect OTC inflows and reserves-to-GDP, respectively. The vectors $I'_{1i,t}$ and $I'_{2i,t}$ are vectors of exogenous variables —country fixed effects, year fixed effects, and banking and currency crisis dummies —that help describe the relationship between $R\_GDP_{i,t}$ and $OTC_{i,t}$. Hence, if the system is well identified, the simultaneous equations model can be used to isolate the effects of financial openness on two endogenous variables, implied by coefficients α_2 and β_2. Moreover, α_1 and β_1 should successfully affirm the effects of OTC inflows on reserves-to-GDP, and *vice versa*, in a well-identified system.

6.2 Data

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 from International Financial Statistics (IFS). First, we exploit the stylized fact that most emerging market debts are traded in OTC markets (see, for instance, Duffie, Gârleanu, and Pedersen (2005)). As such, IFS debt liability flows 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 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 liabilities to debt liabilities 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, note that 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 (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 (private equity firms) who have expertise in evaluating and implementing those potentially high-risk-high-return projects, as well as access to funds (private equity funds). Typically, venture capitalists exert a great deal of resources and time in searching for target firms or projects. Once the two players match, they also bargain over terms of trade, another feature of OTC trade (see, for instance, 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 collected 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.[24] 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.[25] 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, and 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, which carries 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).

With regard to $X'_{i,t}$ and $W'_{i,t}$, we adopt variables widely accepted in the literature. Aizenman and Lee (2007), Cheung and Ito (2009), and Obstfeld, Shambaugh, and Taylor (2010) specified important determinants of international reserves. These regressors include $defacto$ and $dejure$ financial openness from Lane and Milesi-Ferretti (2007b), and Chinn and Ito (2008) respectively, trade openness (import-to-GDP ratio), M2/GDP, exchange rate volatility (annual standard de-

[24] For equities traded in the U.S., the FactSet collects institutional holdings from 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 U.S., it collects ownership data directly from sources such as national regulatory agencies or stock exchange announcements (e.g., the Regulatory News Service in the U.K.), 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.

[25] FactSet classifies individual institutional entities into 27 broad institutional types—investment advisor, hedge fund manager, venture captial/private equity, etc.

viation of monthly exchange rate changes), (log) terms of trade, and peg and soft-peg dummies from Shambaugh (2004); and currency and banking crisis dummies from Laeven and Valencia (2012). We adopt all these variables for $W'_{i,t}$ in our specification.

However, the determinants of OTC inflows are rarely examined empirically. $X'_{i,t}$, therefore, includes sparse controls: (log) population as a measure for country size and (log) GDP per capita as a proxy for a country's quality of financial institutions. Data is collected from World Development Indicators (WDI), the World Bank, International Financial Statistics (IFS), the IMF, and updated and extended versions of Lane and Milesi-Ferretti (2007b)'s dataset. Observations from 71 emerging and developing countries (including developed countries with substantial reserve holdings) for the years 1990-2011 are arranged in an unbalanced panel dataset. The sample countries are listed in Table 1. Table 2 reports the descriptive statistics.

6.3 Empirical Results

Table 3 presents the benchmark results from the system of equations (14) and (15), estimated using a three-stage-least-squares (3SLS) analysis. Table 3 contains only the main variables of our interest, OTC inflows, Reserves/GDP, and financial openness. We isolate the effects of OTC inflows on Reserves/GDP, and *vice versa*, using an exogenous financial openness variable. All columns include country and year fixed effects, and crisis dummies as exogenous variables. Column (1) reports the results for the first model, in which the financial openness measure is included as an explanatory variable only for OTC inflows (debt liabilities + FDI liabilities). The estimated coefficient of Reserves/GDP is significant and positive. The coefficient of financial openness turns out to be significant and positive as well. The lower panel of column (1) shows that the estimated coefficient of OTC inflows on Reserves/GDP is positive and significant at the 1% level. 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 exogenous financial openness variable only for the reserves equation to account for simultaneous endogeneity. The estimated results in column (2) are consistent with those in column (1), and reaffirm the positive relationship between OTC inflows and international reserves 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 Reserves/GDP are positive and significant in columns (3) and (4) respectively. Note that the estimated coefficient of financial openness on venture capital in column (3) is positive but statistically insignificant. These benchmark results strongly support for Proposition 1. However, these results might be biased because we do not fully consider other controls that affect OTC inflows and reserves holdings in the system.

Table 4 shows the main results of this study. Here, other important controls for OTC inflows and Reserves/GDP are included to check the robustness of the results in Table 3. The results in Table 4 are consistent with those in Table 3. In columns (1)-(3), we include various variables of exogenous shocks, financial openness 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 equation for OTC inflows and Reserves/GDP, respectively. The estimated coefficients on Reserves/GDP and OTC inflows are positive and significant at the 1% level. The coefficients on financial openness are positive in both panels although only the one in OTC inflows equation is statistically significant. In columns (2) and (3), we control for financial openness only in either of the two equations. Not only is the positive relationship between OTC inflows and Reserves/GDP preserved but financial openness also has a positive impact on the two endogenous variables. Throughout columns (1)-(3), other explanatory variables have the expected signs for Reserves/GDP. For instance, (log) population, M2/GDP, and trade openness have significant and positive impacts on reserves holdings, consistent with previous findings.

For the robustness of the results, we implement our main simultaneous equations regressions with alternative measures for OTC inflows and financial openness. Table 5 employs the $dejure$ financial openness measure instead of the $defacto$ financial openness measure in our baseline regressions. Tables 6 and 7 introduce alternative measures for OTC inflows. Table 6 uses venture capital inflows. Table 7 considers debt liabilities only as a proxy for OTC inflows. All the results in Tables 5, 6, and 7 support the model's prediction consistently: the estimated coefficients on OTC inflows and Reserves/GDP in the system of equations are positive and statistically significant at the 1% level. Additionally, on the whole, financial openness shows a positive sign for the two key endogenous variables. Note that while the estimated coefficient of financial openness on Reserves/GDP in column (1) of Table 6 is positive, the coefficient of financial openness on venture capital is negative and marginally significant, 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) becomes statistically insignificant. This negative and insignificant inference on financial openness may be caused by the small number of observations for venture capital inflows.

7 Concluding Remarks

Markets through which developing countries acquire foreign capital have been increasingly characterized by OTC features. We argue that this trend is a key to understanding emerging economies' extraordinary 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 reserves holdings lends quite strong support for this liquidity-based story.

One may doubt our liquidity mechanism, given that OTC inflows still take a fraction of total foreign capital inflows into emerging markets in practice. Nonetheless, we do not necessarily think of this as a major caveat to our theory. The reason is that liquidity or collateral benefits of international reserves do not need to be confined to OTC international capital markets. As Lagos (2010, 2011) points out, risk premiums on equity and liquidity premiums on U.S. T-Bonds might as well have a two-way interaction effect to the extent that assets serve as a source of liquidity. Therefore, one could introduce aggregate equity shocks to our framework and show how liquidity benefits of reserves could easily translate from OTC international capital markets to, for instance, emerging equity markets. In fact, a recent study by Qian and Steiner (2014) indeed confirm the aggregate collateral benefits of reserves even within centralized foreign equity investment markets.

Last but not least, the aim of our argument for an alternative understanding of the accumulation of reserves is not to refute existing explanations. Instead, one should view this paper's alternative explanation as complementary to existing ones. We intend for our liquidity based DGE framework to enrich the dimension of research in this field. This framework can be extended to further study interesting research questions. What social welfare effects does reserve accumulation generates in light of the increasing portion of OTC international capital transactions? Is there an optimal degree of decentralization in international capital markets? How does reserve hoarding affect that optimal degree and *vice versa*?

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A Theory Appendix

Proof of Lemma 2.

The participation constraint for the F during this bargaining also depends on how much foreign assets in reference to the first best in the subsequent DM ($\breve{a}$) that F has brought up. We consider three possible scenarios regarding the amount of F's foreign asset holdings.

Scenario 1: $a_f^* \geq \breve{a}$

In this scenario, the bargaining problem simplifies to

$$\max_{\{\kappa,b^*\}} \{u(\kappa) - \beta b^*\},$$
$$s.t. \quad c(\kappa) \leq \beta b^*,$$

with $b^* \leq a_h^*$. Solution for this problem is standard and straightforward. If $a_h^* \geq c(\tilde{\kappa})/\beta$ then, $\kappa = \tilde{\kappa}$ and $b^* = c(\tilde{\kappa})/\beta$. If instead $a_h^* \leq c(\tilde{\kappa})/\beta$ then, $\kappa = \{\kappa : \beta a_h^* = c(\kappa)\}$ and $b^* = a_h^*$. So given the assumption of $a_f^* \geq \breve{a}$, the above two solutions correspond to the region 1 and 2.

Scenario 2: $\breve{a} - b^* \leq a_f^* \leq \breve{a}$

In this scenario, the F would get the first best liquidity amount for the subsequent DM ($\breve{a}$) only after the bargaining. Hence, the bargaining problem is described by

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

with $b^* \leq a_h^*$. First order conditions for this problem follows as:

$$\kappa : u'(\kappa) = \lambda_1 c'(\kappa), \tag{a.1}$$

$$b^* : -\beta + \lambda_1 \beta - \lambda_2 = 0, \tag{a.2}$$

where λ_1 and λ_2 are the associated lagrange multipliers for the above two constraints. Let us consider two possible cases.

When $\lambda_2 = 0$

If we let $\lambda_2 = 0$ then $b^* < a_h^*$ must hold. Since $a_f^* + b^* \geq \check{a}$ by assumption in this scenario, the e.q.(a.1) ensures $\lambda_1 = 1 \Rightarrow \kappa = \tilde{\kappa}$. Moreover, the participation constraint also binds due to $\lambda_1 = 1$. Hence,

$$c(\tilde{\kappa}) = \beta b^* + \sigma \left[u(\tilde{q}) - \tilde{q}\right] - \sigma \left[u(q(a_f^*)) - \beta n(a_f^*)\right]. \tag{a.3}$$

It is understood that the maximum value of b^* must equal to $c(\tilde{\kappa})/\beta$ since e.q.(a.3) implies $b^* \propto a_f^*$ and $\max\{a_f^*\} = \check{a}$ by the assumption. We also need to make sure that these solutions satisfy conditions imposed in this scenario. First, in order to ensure $b^* < a_b^*$ implied by $\lambda_2 = 0$, one needs the following condition based on e.q.(a.3).

$$c(\tilde{\kappa}) - \sigma \left[u(\tilde{q}) - \tilde{q}\right] + \sigma \left[u(q(a_f^*)) - \beta n(a_f^*)\right] < \beta a_h^*. \tag{a.4}$$

On top of that, one would also need to verify $b^* \geq \check{a} - a_f^*$ imposed by the scenario 2 assumption which leads to

$$c(\tilde{\kappa}) - \sigma \left[u(\tilde{q}) - \tilde{q}\right] + \sigma \left[u(q(a_f^*)) - \beta n(a_f^*)\right] \geq \beta(\check{a} - a_f^*). \tag{a.5}$$

Equations (a.4) and (a.5) hold if $a_h^* + a_f^* > \check{a}$ which therefore needs to be imposed. Next, a_f^* must be bounded from below due to the following reason. Combining the e.q.(a.4) and (a.5) generates

$$\sigma \left[u(\beta a_f^*) - \beta a_f^*\right] + \beta a_f^* \geq \beta \check{a} + \sigma \left[u(\check{q}) - \check{q}\right] - c(\tilde{\kappa}). \tag{a.6}$$

This e.q.(a.6) confirms that $\exists \bar{a}_f^*$ such that

$$\sigma \left[u(\beta a_f^*) - \beta a_f^*\right] + \beta a_f^* = \beta \check{a} + \sigma \left[u(\check{q}) - \check{q}\right] - c(\tilde{\kappa}). \tag{a.7}$$

Note here the condition $a_h^* + a_f^* > \check{a}$ imposed above is redundant as long as e.q.(a.4) holds and $a_f^* > \bar{a}_f^*$ since the LHS of inequality e.q.(a.4) is increasing in a_f^* while $\check{a} - a_f^*$ falls with a_f^*. It is also important to notice that the relative size of cost of producing *capital goods* during the FIM critically determines the sign of $\bar{a}_f^*$. If $c(\tilde{\kappa})$ turns out to be greater than $\beta\breve{a} + \sigma\left[u(\breve{q}) - \breve{q}\right]$ then it is obvious that $\bar{a}_f^*$ must be a negative value otherwise $\bar{a}_f^*$ becomes positive. Hence, the bargaining solution depends on the set of parameter space for $c(\tilde{\kappa}), u(\tilde{q})$, and $\breve{a}$. For now, let us restrict ourselves to the case, $c(\tilde{\kappa}) < \beta\breve{a} + \sigma\big[u(\tilde{q}) - \tilde{q}\big]$ and consider the other case later. To sum up, for the solution to be $\kappa = \tilde{\kappa}$ and $b^* < a_h^*$ such that e.q.(a.3) holds

1. $\bar{a}_f^* \leq a_f^* \leq \breve{a}$,
2. $a_h^* \geq \left\{c(\tilde{\kappa}) - \sigma\left[u(\tilde{q}) - u(\beta a_f^*) + \tilde{q} - \beta a_f^*\right]\right\}/\beta$.

which corresponds to the region 3 solution.

When $\lambda_2 > 0$

If we let $\lambda_2 > 0$ then, $b^* = a_h^*$ must hold. Since $a_f^* + b^* \geq \breve{a}$ by assumption in this scenario, $a_f^* + a_h^* \geq \breve{a}$ and the e.q.(a.1) ensures $\lambda_1 > 1 \Rightarrow \kappa < \tilde{\kappa}$. Moreover, the participation constraint also binds due to $\lambda_1 > 1$. Hence the solution for κ must satisfy

$$\begin{aligned} c(\kappa) &= \beta a_h^* + \sigma\left[u(\tilde{q}) - \tilde{q}\right] - \sigma\left[u(q(a_f^*)) - q(a_f^*)\right], \\ c(\tilde{\kappa}) &> \beta a_h^* + \sigma\left[u(\tilde{q}) - \tilde{q}\right] - \sigma\left[u(q(a_f^*)) - q(a_f^*)\right], \\ a_h^* &\leq \frac{c(\tilde{\kappa}) - \sigma\left[u(\tilde{q}) - u(\beta a_f^*) + \tilde{q} - \beta a_f^*\right]}{\beta}. \end{aligned} \tag{a.8}$$

Furthermore, combining e.q.(a.8) with $a_h^* \geq \breve{a} - a_f^*$ yields

$$\begin{aligned} c(\kappa) - \sigma\left[u(\tilde{q}) - \tilde{q}\right] + \sigma\left[u(q(a_f^*)) - q(a_f^*)\right] &\geq \beta(\breve{a} - a_f^*) \\ \sigma\left[u(\beta a_f^*) - \beta a_f^*\right] + \beta a_f^* &\geq \beta\breve{a} + \sigma\left[u(\breve{q}) - \breve{q}\right] - c(\kappa). \end{aligned} \tag{a.9}$$

From e.q.(a.7) and (a.9), it is understood that $a_f^* > \bar{a}_f^*$ in this case 2 as well. Thus for the solution to be $b^* = a_h^*$ and $\kappa < \tilde{\kappa}$ such that e.q.(a.8) holds

1. $\bar{a}_f^* \leq a_f^* \leq \breve{a}$,
2. $a_h^* + a_f^* \geq \breve{a}$,
3. $a_h^* \leq \left\{c(\tilde{\kappa}) - \sigma\left[u(\tilde{q}) - u(\beta a_f^*) + \tilde{q} - \beta a_f^*\right]\right\}/\beta$,

which corresponds to the region 4.
Scenario 3: $a_f^* + b^* \leq \breve{a}$
In this scenario, the F would never get the first best liquidity amount for the subsequent DM,

i.e., $\check{a}$, even after the bargaining. Hence, the bargaining problem is described by

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

with $b^* \leq a_h^*$. First order conditions for this problem follows as:

$$\kappa : u'(\kappa) = \lambda_1 c'(\kappa), \tag{a.10}$$
$$b^* : -\beta + \lambda_1\left[\beta + \sigma u'(q(a_f^* + b^*))\beta - \sigma\beta\right] - \lambda_2 = 0, \tag{a.11}$$

where λ_1 and λ_2 are associated Lagrange multipliers for the above two constraints. Let us consider two possible cases.

<u>*When $\lambda_2 = 0$*</u>

If we let $\lambda_2 = 0$ then, the second constraint becomes slack, i.e., $b^* < a_h^*$. Also from e.q.(a.11) it is obvious that $\lambda_1 < 1 \Rightarrow \kappa > \tilde{\kappa}$. Again the first constraint binds due to positive value of λ_1 and therefore, the following must hold

$$c(\kappa) = \beta b^* + \sigma\left[u(q(a_f^* + b^*)) - \beta n(a_f^* + b^*)\right] - \sigma\left[u(q(a_f^*)) - \beta n(a_f^*)\right] > c(\tilde{\kappa}). \tag{a.12}$$

As before, we again need to make sure that these solutions satisfy conditions imposed in this scenario. First, in order to ensure $b^* < a_h^*$ stemming from $\lambda_2 = 0$, one needs the following condition based on e.q.(a.12)

$$c(\kappa) - \sigma\left[u(q(a_f^* + b^*)) - \beta n(a_f^* + b^*)\right] + \sigma\left[u(q(a_f^*)) - \beta n(a_f^*)\right] < \beta a_h^* \tag{a.13}$$
$$c(\kappa) - \sigma\left[u(q(a_f^* + b^*)) - u(q(a_f^*))\right] + \sigma\beta b^* < \beta a_h^*.$$

On top of that, one would also need to verify $b^* \leq \check{a} - a_f^*$ imposed by the scenario 3 assumption which gives out

$$c(\kappa) - \sigma\left[u(q(a_f^* + b^*)) - \beta n(a_f^* + b^*)\right] + \sigma\left[u(q(a_f^*)) - \beta n(a_f^*)\right] < \beta(\check{a} - a_f^*) \tag{a.14}$$
$$\sigma u(\beta a_f^*) + (1-\sigma)\beta a_f^* < \beta\check{a} + \sigma\left[u(q(a_f^* + b^*)) - q(a_f^* + b^*)\right] - c(\kappa). \tag{a.15}$$

Now the question is whether $a_h^* + a_f^* < \check{a}$ or not. From e.q.(a.12), it is easy to see that

$$\sigma u(q(a_f^*)) = (1-\sigma)\beta b^* + \sigma u(q(a_f^* + b^*)) - c(\kappa), \tag{a.16}$$

which confirms that $\{b^*, \kappa\}$ is not uniquely determined, and yet positively related ($b^* \propto \kappa$). This in turn ensures that a_h^* must be bounded from below for the following reason. Due to $b^* \propto \kappa$,

$c(\kappa) > c(\tilde{\kappa})$ and e.q.(a.16), minimum value for b^*, b^*_m is such that

$$c(\tilde{\kappa}) = \sigma\big[u(q(a^*_f + b^*_m)) - u(q(a^*_f))\big] + (1-\sigma)\beta b^*_m. \tag{a.17}$$

By the implicit function theorem, e.q.(a.17) confirms $\partial b^*_m / \partial a^*_f > 0$

$$\frac{\partial b^*_m}{\partial a^*_f} = -\frac{\frac{\partial G}{\partial a^*_f} \to \ominus}{\frac{\partial G}{\partial b^*_m} \to \oplus} > 0,$$

where $G(b^*_m, a^*_f) = \sigma\big[u(q(a^*_f + b^*_m)) - u(q(a^*_f))\big] + (1-\sigma)\beta b^*_m - c(\tilde{\kappa})$ and

$$\frac{\partial G}{\partial a^*_f} = \sigma\beta\big[u'(q(a^*_f + b^*_m)) - u'(q(a^*_f))\big] < 0 \quad \text{due to the concavity assumption of } u(\cdot),$$
$$\frac{\partial G}{\partial b^*_m} = \sigma\beta\big[u'(q(a^*_f + b^*_m)) - 1\big] + \beta b^* > 0 \quad \text{due to } a^*_f + b^* < \check{a}.$$

Thus $\min\{a^*_h\}$ ($a^*_{h,Min}$) must be an increasing function of a^*_f. In addition, when $a^*_f = 0$ the $a^*_{h,Min}$ must satisfy the following

$$c(\tilde{\kappa}) = \sigma u(q(a^*_{h,Min})) + (1-\sigma)\beta a^*_{h,Min}. \tag{a.18}$$

Since we earlier restricted the parameter space into *Case 1* such that $c(\tilde{\kappa}) < \sigma\big[u(\tilde{q}) - \tilde{q}\big] + \beta\check{a}$, one can easily verify that $a^*_{h,Min} < \check{a}$. Lastly we need to verify that when $a^*_f = \bar{a}^*_f$, $a^*_{h,Min}$ is such that $a^*_{h,Min} + a^*_f = \check{a}$ so that the feasible domain for a^*_f in this scenario must be bounded from above, i.e., $\bar{a}^*_f$. This can be done easily by comparing e.q.(a.17) and (a.3). Considering the knife-edge case between region 3 and this region, e.q.(a.3) and (a.17) respectively gives out

$$c(\tilde{\kappa}) - \sigma u(\tilde{q}) + \sigma u(\beta\bar{a}^*_f) + \sigma\beta a^*_h = \beta a^*_h, \tag{a.19}$$
$$c(\tilde{\kappa}) - \sigma u(q(\bar{a}^*_f + b^*_m)) + \sigma u(\beta\bar{a}^*_f) + \sigma\beta b^*_m = \beta b^*_m. \tag{a.20}$$

These two equations become identical when $b^*_m = a^*_h$ and therefore, $a^*_{h,Min} + a^*_f = \check{a}$ must hold at this knife-edge case of $a^*_f = \bar{a}^*_f$. To sum up, for the indeterminate combination of $(\kappa, b^*) = \big\{(\kappa, b^*) : \kappa > \tilde{\kappa}, b^* < a^*_h, b^* < \check{a} - a^*_f, c(\kappa) = (1-\sigma)\beta b^* + \sigma\big[u(\beta(a^*_f + b^*) - u(\beta a^*_f)\big]\big\}$ to be the solution, the following restrictions on a^*_h and a^*_f must hold true

1. $a^*_h \geq a^*_{h,Min}$,
2. $a^*_f \leq \bar{a}^*_f$,

which corresponds to region 5.

When $\lambda_2 > 0$

If we let $\lambda_2 > 0$ then, $b^* = a_h^*$ must hold. Moreover, the participation constraint also binds due to $\lambda_1 > 0$. Hence the solution for κ must satisfy

$$c(\kappa) = (1-\sigma)\beta a_h^* + \sigma\left[u(q(a_f^* + a_h^*)) - u(q(a_f^*))\right]. \tag{a.21}$$

Now the question is whether κ here is bigger or less than $\tilde{\kappa}$. As a matter of fact, it can be easily shown that $c(\kappa) < c(\tilde{\kappa})$ in this case. First, the comparison between e.q.(a.21) and (a.17) confirm that $c(\kappa) \leq c(\tilde{\kappa})$ if $a_f^* \leq \bar{a}_f^*$. Second, if $a_f^* \geq \bar{a}_f^*$ and $a_f^* + a_h^* < \check{a}$ then e.q.(a.21) tells us that the max of $c(\kappa)$ ($c(\kappa^{max})$) occurs at the point where $a_f^* = \bar{a}_f^*$ and $a_h^* = \check{a} - \bar{a}_f^*$ due to again the concavity assumption on $u(\cdot)$. Thus plugging $a_f^* = \bar{a}_f^*$ and $a_h^* = \check{a} - \bar{a}_f^*$ into e.q.(a.21) would yield the condition for $c(\kappa^{max})$ as

$$\begin{aligned} c(\kappa^{max}) &= (1-\sigma)\beta(\check{a} - \bar{a}_f^*) + \sigma\left[u(\tilde{q}) - u(q(\bar{a}_f^*))\right] \\ &= (1-\sigma)\beta a_h^* + \sigma\left[u(\tilde{a}) - u(q(\bar{a}_f^*))\right], \end{aligned} \tag{a.22}$$

which is same as e.q.(a.19). This completes the proof that $c(\kappa)$ regardless of a_f^* domain becomes bounded from above, $c(\tilde{\kappa})$ in this case. To sum up, for the $b^* = a_h^*$ and κ such that e.q.(a.21) holds to be the solution, the following condition should be met

1. $a_h^* \leq a_{h,Min}^*$,
2. $a_f^* \leq \check{a} - a_h^*$.

which corresponds to region 6.

Lastly, let us consider the parameter space such that $\beta\check{a} + \sigma\left[u(\tilde{q}) - \tilde{q}\right] \leq c(\tilde{\kappa})$. In this case, $\bar{a}_f^*$ becomes negative. This essentially eliminates the indeterminate solution region 5. The reason for this disappearance is quite intuitive. Recall the participation constraint for the F in the FIM bargaining problem. The F's liquidity evaluation of foreign assets, i.e., $\sigma u(q(a_f^* + b^*)) - \sigma\beta n(a_f^* + b^*) - \sigma\left[u(q(a_f^*)) - \beta n(a_f^*)\right]$, even when the her initial foreign asset holdings are zero should reach an upper bound. Once the disutility of producing $\tilde{\kappa}$, i.e., $c(\tilde{\kappa})$, exceeds this boundary, the F would never be willing to produce more than $\tilde{\kappa}$ and the terms of trade would never settle at the point where $\kappa > \tilde{\kappa}$ even if a_f^* falls into zero as shown in Figure 6. All the other conditions regarding the remaining regions stay same. The following summarizes and graphically illustrates the bargaining solution under this new parameter space.

$$\textit{If} \quad \begin{cases} a_h^* \geq \frac{c(\tilde{\kappa})}{\beta} \\ a_f^* \geq \check{a} \end{cases} \quad \textit{then} \quad \begin{cases} \kappa = \tilde{\kappa} \\ b^* = \frac{c(\tilde{\kappa})}{\beta} \end{cases} \quad \Rightarrow \textit{Region 1},$$

$$\textit{If}\quad \begin{cases} a_h^* \le \frac{c(\tilde{\kappa})}{\beta} \\ a_f^* \ge \breve{a} \end{cases} \quad \textit{then} \quad \begin{cases} \kappa = \{\kappa : \beta a_h^* = c(\kappa)\} \\ b^* = a_h^* \end{cases} \quad \Rightarrow \textit{Region 2,}$$

$$\textit{If}\quad \begin{cases} a_h^* \ge \frac{c(\tilde{\kappa})-\sigma\left[u(\tilde{q})-u(\beta a_f^*)+\tilde{q}-\beta a_f^*\right]}{\beta} \\ a_f^* \le \breve{a} \end{cases} \quad \textit{then} \quad \begin{cases} \kappa = \tilde{\kappa} \\ b^* = \frac{c(\tilde{\kappa})-\sigma\left[u(\tilde{q})-u(\beta a_f^*)+\tilde{q}-\beta a_f^*\right]}{\beta} \end{cases} \quad \Rightarrow \textit{Region 3,}$$

$$\textit{If}\quad \begin{cases} a_h^* \le \frac{c(\tilde{\kappa})-\sigma\left[u(\tilde{q})-u(\beta a_f^*)+\tilde{q}-\beta a_f^*\right]}{\beta} \\ \breve{a} - a_h^* \le a_f^* \le \breve{a} \end{cases} \quad \textit{then} \quad \begin{cases} \kappa = \big\{\kappa : c(\kappa) = \beta a_h^* \\ \quad +\sigma\big[u(\tilde{q}) - u(\beta a_f^*) - \tilde{q} + \beta a_f^*\big]\big\} \\ b^* = a_h^* \end{cases} \quad \Rightarrow \textit{Region 4,}$$

$$\textit{If}\quad a_f^* + a_h^* \le \breve{a} \quad \textit{then} \quad \begin{cases} \kappa = \big\{\kappa : c(\kappa) = \beta a_h^* + \sigma\big[u(\beta(a_f^* + a_h^*)) - u(\beta a_f^*)\big] \\ \quad -\sigma\big[\beta(a_f^* + a_h^*) - \beta a_f^*\big]\big\} \\ b^* = a_h^* \end{cases} \quad \Rightarrow \textit{Region 6.}$$

This completes the proof. *Q.E.D*

Proof of Lemma 3.

From the *Case 1* in Lemma 3, it is easy to check that the terms of trade in the FIM in regions 1,3, and 5 have nothing to do with $\widehat{a}_h^*$. Thus the third line e.q.(11) basically becomes a constant term. This makes the first derivative of J^H with respect to $\widehat{a}_h^*$ simply equal to $-\psi^* + \beta$. On the contrary, the H would experience the liquidity shortage in region 2,4, and 6. Therefore she would have to give up all of her foreign asset holdings during the FIM bargaining. This would in turn cause κ to depend on $\widehat{a}_h^*$ as well. Thus the partial derivatives in these regions should take a form as

$$\frac{\partial J_i^H(\widehat{a}_h, \widehat{a}_h^*)}{\partial \widehat{a}_h^*} = -\psi^* + \beta + \chi_h \beta \left\{ u'(\kappa(\cdot)) \frac{\partial \kappa(\cdot)}{\partial \widehat{a}_h^*} - \beta \frac{\partial b^*(\cdot)}{\partial \widehat{a}_h^*} \right\} \quad i = 2, 4, 6,$$

$\partial b^*(\cdot)/\partial \widehat{a}_h^* = 1$ since $b^* = a_h^*$ for all regions of 2,4, and 6. Applying the Implicit Function Theorem to the FIM bargaining protocol described in *Case 1* of Lemma 3 indicates

$$\frac{\partial \kappa(\cdot)}{\partial \widehat{a}_h^*} = \begin{cases} -\frac{-\beta}{c'(\kappa)} & \text{if} \quad i = 2, 4, \\ -\frac{-\beta - \sigma u'(\beta(a_f^* + a_h^*))\beta + \sigma\beta}{c'(\kappa)} & \text{if} \quad i = 6. \end{cases}$$

This completes the proof. *Q.E.D*

Proof of Lemma 4.

The budget constraint of the centralized market implies that the H can exploit more labor units in period t by dL_t^h and get either $\psi_{t+1} dB_{t+1}^h$ units of home bonds or $\psi_{t+1}^* dR_{t+1}^h$ units of foreign reserves. In the next period the H can therefore decrease the amount labor units exploited by

$dL^h_{t+1} = dB^h_{t+1}$ or dR^h_{t+1}. The net utility gain of doing this strategy is

$$\begin{aligned} d\mathcal{U}^h_t = -dL^h_t + \beta dL^h_{t+1} &= -\, dB^h_{t+1}\left[\psi_{t+1} - \beta\right] \\ &= -\, dR^h_{t+1}\left[\psi^*_{t+1} - \beta\right]. \end{aligned}$$

So, either of $\beta > \psi_{t+1}$ or $\beta > \psi^*_{t+1}$ implies that $d\mathcal{U}_t > 0$ which would in turn cause for infinite labor demand every period. Therefore in any any equilibrium $\beta \le \psi$ and $\beta \le \psi^*$. This can be applied to the F exactly in the same way. By the similar budget constraint of the F in the centralized market, F can also exploit more labor units in period t by dL^f_t and get dR^f_{t+1} units of foreign assets. In the next period the F can therefore decrease the amount labor units exploited by $dL^f_{t+1} = dR^f_{t+1}$. The net utility gain of doing this strategy is

$$d\mathcal{U}^f_t = -dL^f_t + \beta dL^f_{t+1} = -dR^f_{t+1}\left[\psi^*_{t+1} - \beta\right].$$

Again, this confirms that in any any equilibrium $\beta \le \psi^*$. *Q.E.D*

Proof of Lemma 5.

Consider the case where $\widehat{a}^*_f > \check{a}$. It becomes obvious from Lemma 1 that the terms of trade in the F's local DM are fixed regardless of the amount of foreign assets the F chooses to hold. Hence by taking the first order condition of e.q.(13) with respect to $\widehat{a}^*$, we obtain

$$J^F_{\widehat{a}^*}(\widehat{a}^*) = -\psi^* + \beta \le 0,$$

where the weak inequality sign comes from Lemma (4). From this one can easily verify that the optimal choice of foreign asset holdings for the F can be no greater than or equal to $\check{a}$ unless $\psi^* = \beta$. We now consider the second case where $\widehat{a}^*_f \le \check{a}$. Again following from the bargaining solution in Lemma (1) we have a FOC as

$$J^F_{\widehat{a}^*}(\widehat{a}^*) = -\psi^* + \beta + \sigma\beta\left\{u'(q(a^*_f)) - 1\right\}.$$

This justifies the optimality condition in Lemma 5. For the uniqueness of $\widetilde{a^*_f}$, we need following observations. Given the strict concavity assumption of agent's utility function, it is easy to understand that the second derivative of the F's objective function with respect to $\widehat{a}^*$ is strictly negative, i.e., $J^F_{\widehat{a}^*\widehat{a}^*}(\widehat{a}^*) < 0$ for all $\widehat{a}^* \in (0, \check{a}]$. Furthermore, one can also easily show that the following two conditions must hold in the limit.

$$\lim_{\widehat{a}^* \to 0} J^F_{\widehat{a}^*}(\widehat{a}^*) > 0,$$

$$\lim_{\widehat{a}^* \to \check{a}^-} J^F_{\widehat{a}^*}(\widehat{a}^*) \le 0.$$

Combining all these results above, we can finally conclude that the optimal choice of $\widetilde{a}_f^*$ is unique, and it satisfies $\widetilde{a_f^*} \in (0, \check{a})$ when $\psi^* < \beta$. On the other hand, if ψ^* happens to be same as β then, the F's optimal foreign asset holdings could be either same as $\check{a}$ or anything bigger than that. *Q.E.D*

Proof of Lemma 6.

With regard to the optimal home asset holdings ($\widetilde{a}$), one can refer to the proof of Lemma 5 since the exactly same line of reasoning applies. From Lemma 3 and 3, one can infer the parameter space of (ψ^*, a_f^*) that is consistent with the optimal choice of $\widetilde{a_h^*}$ in each of the six regions.

Region 1: First, from Lemma 3, the optimality requires that $\psi^* = \beta$. Second, Lemma 3 restricts $\widetilde{a_h^*}$ to be greater than or equal to $c(\tilde{\kappa})/\beta$.

Region 2: The optimality condition based on Lemma 3 asks $\psi^* - \beta = \chi_h \beta \left\{u'(\kappa)/c'(\kappa) - 1\right\}$. Since the Lemma 3 implies $\kappa < \tilde{\kappa}$ in this region, the optimality should be consistent with $\psi^* > \beta$.

Region 3: The optimal condition based on Lemma 3 implies $\psi^* = \beta$. At the same time, Lemma 3 pins down the $\widetilde{a}_h^*$ such that $\widetilde{a_h^*} = \mathbb{R}_{++} \geq c(\tilde{\kappa})/\beta - \sigma\left[u(\tilde{q}) - u(\beta\widehat{a}_f^*) + \tilde{q} - \beta\widehat{a}_f^*\right]/\beta$.

Region 4: Lemma 3 restricts $\widetilde{a}_h^*$ to be less than $c(\tilde{\kappa})/\beta$, and hence implies $\kappa < \tilde{\kappa}$. At the same time, the optimality from Lemma 3 requires $\psi^* - \beta = \chi_h \beta \left\{u'(\kappa)/c'(\kappa) - 1\right\}$. Combining the two results, it is obvious that the optimality should be consistent with $\psi^* > \beta$. Nevertheless, the upper bound of ψ^* ($\overline{\psi^*}$) that is consistent with the optimality should exist. This condition is attributed to the fact that the Lemma 3 also bounds $\widetilde{a_h^*}$ from below ($\check{a} - a_f^*$). If ψ^* grows too big, the optimal amount of $\widetilde{a_h^*}$ defined in Lemma 3 may fall below $\check{a} - a_f^*$. In order to prevent this, $\overline{\psi^*}$ should be such that it satisfies the optimality, i.e., $\overline{\psi^*} - \beta = \chi_h \beta \left\{u'(\kappa)/c'(\kappa) - 1\right\}$) given κ that guarantees the minimum value of $\widetilde{a_h^*}$, i.e., $c(\kappa) = \sigma\left[u(\tilde{q}) - \tilde{q}\right] - \sigma\left[u(q(\widehat{a}_f^*)) - q(\widehat{a}_f^*)\right] + \beta(\hat{a} - \widehat{a}_f^*)$.

To the right side of $\bar{a}_f^*$ in Region 6: Similar to the region 4 case, Lemma 3 restricts $\widetilde{a}_h^*$ such that $\kappa < \tilde{\kappa}$. Given the optimal condition of $\psi^* - \beta = \chi_h \beta \left\{u'(\kappa)/c'(\kappa)\left\{(1-\sigma) + \sigma u'(\beta\widehat{a}_f^*)\right\} - 1\right\}$ from Lemma 3, the optimality should imply $\psi^* > \beta$. However, the region 4 case shows that foreign asset price range of $\beta < \psi^* < \overline{\psi^*}$ should lead to the $\widetilde{a}_h^*$, which dominates the one implied by the optimality in this region. For this reason, only $\psi^* > \overline{\psi^*}$ is compatible with the optimal choice in this region.

Region 5: From Lemma 3, the optimality requires that $\psi^* = \beta$. Moreover, proof for Lemma 3 restricts $\widetilde{a_h^*}$ to be greater than or equal to $a_{h,Min}^*$.

To the left side of $\bar{a}_f^*$ in Region 6: The optimality condition based on Lemma 3 asks $\psi^* - \beta = \chi_h \beta \left\{u'(\kappa)/c'(\kappa)\left\{(1-\sigma) + \sigma u'(\beta\widehat{a}_f^*)\right\} - 1\right\}$. Since the Lemma 3 implies $\kappa < \tilde{\kappa}$ in this region, the optimality should be consistent with $\psi^* > \beta$.

Rearranging the results above should suffice to explain the H's optimal choice of foreign asset holdings. This completes the proof. *Q.E.D*

Proof of Lemma 7.

When T^* is plentiful: $T^* \geq \breve{a} + c(\tilde{\kappa})/\beta$

Figure 3 confirms that the region 1, 2, 3, and 5 could be all potentially possible equilibrium region. It is obvious from Lemma 5 and 6 that $\psi^* = \beta$ if the equilibrium happens to occur in either of these regions.

(i): Now suppose the equilibrium (a_h^*, a_f^*) lies in the region 2. Then Lemma 5 tells that $a_f^* > \breve{a}$ must be consistent with $\psi^* = \beta$. Yet, $\partial J_2^H(\widehat{a}_h, \widehat{a}_h^*)/\partial \widehat{a}_h^*$ from the Lemma 3 implies that $\kappa = \tilde{\kappa}$ which is a contradiction to Lemma 3. Thus the region 2 can not be the equilibrium region.

(ii): Suppose the equilibrium lies in either of the region 3 or 5. Then the Lemma 5 tells that $\psi^* > \beta$ but again from $\partial J_3^H(\widehat{a}_h, \widehat{a}_h^*)/\partial \widehat{a}_h^*$ or $\partial J_3^H(\widehat{a}_h, \widehat{a}_h^*)/\partial \widehat{a}_h^*$ from the Lemma 3 indicates that only $\psi^* = \beta$ must be consistent with the H's optimality. Hence, the region 3 can not be the equilibrium region either.

(iii): Suppose the equilibrium lies in the region 1. Then the Lemma 5 implies $\psi^* = \beta$. At the same time, $\partial J_1^H(\widehat{a}_h, \widehat{a}_h^*)/\partial \widehat{a}_h^*$ from the Lemma 3 also confirms that $\psi^* = \beta$ is consistent with the H's optimality. Hence, the equilibrium can be achieved in this regions subject to:

1. $a_h^* \geq c(\tilde{\kappa})/\beta$
2. $a_f^* \geq \breve{a}$
3. $a_h^* + a_f^* = T^*$.

As long as any combination of (a_h^*, a_f^*) meets the above three conditions, the equilibrium can be achieved and therefore, the indeterminacy arises in this case.

When T^* lies within a moderate range: $\breve{a} \leq T^* < \breve{a} + c(\tilde{\kappa})/\beta$

It is understood that the region 2, 3, and 5 can not be the equilibrium region for the same reason as in the case of $T^* \geq \breve{a} + c(\tilde{\kappa})/\beta$. This only leaves us with the region 4 as the only feasible equilibrium region. Indeed the Lemma 5 and 6 restrict the foreign asset price to be greater than the fundamental value in this region. Specifically, the two optimal conditions at the market clearing situation are:

$$\psi^* - \beta = \sigma\beta\left[u'(\beta a_f^*) - 1\right], \tag{a.23}$$

$$\psi^* - \beta = \chi_h\beta\left[\frac{u'(\kappa)}{c'(\kappa)} - 1\right], \tag{a.24}$$

$$where \quad c(\kappa) = \beta(T^* - a_f^*) + \sigma\left[u(\tilde{q}) - u(\beta a_f^*) - \tilde{q} + \beta a_f^*\right].$$

From e.q(a.23) and (a.24) the following must be satisfied in equilibrium as well.

$$\frac{\chi_h}{\sigma} = \frac{u'(\beta a_f^*) - 1}{u'(\kappa)/c'(\kappa) - 1}. \tag{a.25}$$

Finally let us prove if $\exists ! a_f^* \in (\bar{a}_f^*, \breve{a})$. By rearranging e.q(a.25), one can define $G(a_f^*)$ as:

$$G(a_f^*) \equiv \sigma \left\{ u'(\beta a_f^*) - 1 \right\} - \chi_h \left\{ \frac{u'(\kappa)}{c'(\kappa)} - 1 \right\} = 0, \tag{a.26}$$

$$where \quad c(\kappa) = \beta(T^* - a_f^*) + \sigma \big[u(\tilde{q}) - u(\beta a_f^*) - \tilde{q} + \beta a_f^* \big]. \tag{a.27}$$

First, by taking the $G(a_f^*)$ to the limit the following must hold.

$$\begin{aligned} \lim_{a_f^* \to \bar{a}_f^{*+}} G(a_f^*) =& \sigma \Big\{ u'(\beta \bar{a}_f^*) - 1 \Big\} - \chi_h \Big\{ \frac{u'(\tilde{\kappa})}{c'(\tilde{\kappa})} - 1 \Big\} && \text{(a.28)} \\ =& \oplus - 0 > 0, \\ \lim_{a_f^* \to \breve{a}^-} G(a_f^*) =& \sigma \Big\{ u'(\beta \breve{a}) - 1 \Big\} - \chi_h \Big\{ \frac{u'(\kappa)}{c'(\kappa)} - 1 \Big\} && \text{(a.29)} \\ =& 0 - \oplus < 0, \end{aligned}$$

where the second term in e.q(a.29) becomes a negative value since the κ in the region 4 happens to be less than $\tilde{\kappa}$ according to the Lemma 3.

$$\begin{aligned} G'(a_f^*) =& \sigma \beta \underbrace{u''(\beta a_f^*)}_{\ominus} && \text{(a.30)} \\ & - \chi_h \Big\{ \underbrace{u''(\kappa)}_{\ominus} \underbrace{\frac{\partial \kappa}{\partial a_f^*}}_{\ominus} c'(\kappa)^{-1} - u' c'(\kappa)^{-2} \underbrace{c''(\kappa)}_{\oplus} \underbrace{\frac{\partial \kappa}{\partial a_f^*}}_{\ominus} \Big\} < 0. \end{aligned}$$

Finally, all is left to guarantee the uniqueness of equilibrium a_f^* is to show that $G'(a_f^*) < 0$ as shown in e.q. a.30 where $\partial \kappa / \partial a_f^* = -\{(1-\sigma)\beta + \sigma u'(\beta a_f^*)\} / c'(\kappa) < 0$ from the e.q(a.27). This proves $G'(a_f^*) < 0$ and therefore, the uniqueness of the equilibrium in the region 4 is established.

When T^* is scarce: $T^* \leq \breve{a}$

Potentially the equilibrium a_h^*, a_f^* can be in either region 5 and 6. Again It is obvious that the region 5 can not be the equilibrium region for the same reason in the previous two cases. This only leaves us with the region 6 as the only feasible equilibrium region. Indeed the Lemma 5 and 6 restrict the foreign asset price to be greater than the fundamental value in this region. Specifically, the two optimal conditions are:

$$\begin{aligned} \psi^* - \beta &= \sigma \beta \left[u'(\beta a_f^*) - 1 \right], && \text{(a.31)} \\ \psi^* - \beta &= \chi_h \beta \left[u'(\kappa) / c'(\kappa) \left\{ (1-\sigma) + \sigma u'(\beta T^*) \right\} - 1 \right], && \text{(a.32)} \\ where \quad c(\kappa) =& \beta(T^* - a_f^*) + \sigma \left[u(\beta T^*) - u(\beta a_f^*) + \beta(T^* - a_f^*) \right]. \end{aligned}$$

From e.q(a.31) and (a.32) the following must be satisfied in equilibrium as well.

$$\frac{\chi_h}{\sigma} = \frac{u'(\beta a_f^*) - 1}{u'(\kappa)/c'(\kappa)\left\{(1-\sigma) + \sigma u'(\beta T^*)\right\} - 1}. \tag{a.33}$$

Finally let us prove if $\exists! a_f^* \in (0, \breve{a})$. By rearranging e.q(a.33), one can define $Z(a_f^*)$ as

$$Z(a_f^*) \equiv \sigma\Big\{u'(\beta a_f^*) - 1\Big\} - \chi_h\left\{\frac{u'(\kappa)}{c'(\kappa)}\left\{(1-\sigma) + \sigma u'(\beta T^*)\right\} - 1\right\} = 0, \tag{a.34}$$

$$where \quad c(\kappa) = \beta(T^* - a_f^*) + \sigma\big[u(\beta T^*) - u(\beta a_f^*) + \beta(T^* - a_f^*)\big]. \tag{a.35}$$

First, by taking the $Z(a_f^*)$ to the limit the following must hold.

$$\lim_{a_f^* \to 0^+} Z(a_f^*) = \sigma\Big\{u'(\beta 0) - 1\Big\} - \chi_h\left\{\frac{u'(\kappa)}{c'(\kappa)}\left\{(1-\sigma) + \sigma u'(\beta T^*)\right\} - 1\right\} \tag{a.36}$$

$$= \infty - \oplus > 0,$$

$$\lim_{a_f^* \to \breve{a}^-} Z(a_f^*) = \sigma\Big\{u'(\tilde{q}) - 1\Big\} - \chi_h\left\{\frac{u'(\kappa)}{c'(\kappa)}\left\{(1-\sigma) + \sigma u'(\beta T^*)\right\} - 1\right\} \tag{a.37}$$

$$= 0 - \oplus < 0,$$

where the second term in e.q(a.37) becomes a negative value since the κ in the region 6 happens to be less than $\tilde{\kappa}$ according to the Lemma 3. Finally all is left to guarantee the uniqueness of equilibrium a_f^* is to show that $Z'(a_f^*) < 0$. By taking the first derivative of $Z(a_f^*)$ function with respect to a_f^*, the following equation must hold true.

$$\begin{aligned} Z'(a_f^*) =& \sigma\beta\underbrace{u''(\beta a_f^*)}_{\ominus} \\ & - \chi_h \underbrace{\left\{(1-\sigma) + \sigma u'(\beta T^*)\right\}}_{\oplus}\left\{\underbrace{u''(\kappa)}_{\ominus}\underbrace{\frac{\partial \kappa}{\partial a_f^*}}_{\ominus} c'(\kappa)^{-1} - u'c'(\kappa)^{-2}\underbrace{c''(\kappa)}_{\oplus}\underbrace{\frac{\partial \kappa}{\partial a_f^*}}_{\ominus}\right\} < 0, \end{aligned} \tag{a.38}$$

where $u'(\beta T^*) \leq u'(\tilde{q}) = 1$ and $\partial\kappa/\partial a_f^* = -\{(1-\sigma)\beta + \sigma u'(\beta a_f^*)\}/c'(\kappa) < 0$ from the e.q(a.35). This proves $Z'(a_f^*) < 0$ and therefore, the uniqueness of the equilibrium in the region 4 is established. *Q.E.D.*

Proof of Proposition 1.

We first prove for the effects of T^* on various equilibrium objects. To that end, we separately provide proofs for each case, i,e., $\breve{a} < T^* \leq \breve{a} + c(\tilde{\kappa})/\beta$ and $T^* < \breve{a}$.

When $\breve{a} < T^* \leq \breve{a} + c(\tilde{\kappa})/\beta$

It is obvious that the home country would on aggregate hold on to home assets exceeding the first best amount $\check{a}$. Then from Lemma 6, $\psi = \beta$ must hold in equilibrium. Since the proof for the Lemma 7 confirms $\psi^* > \beta$ for the case $\check{a} < T^* \leq \check{a} + c(\tilde{\kappa})/\beta$, it should be easy to see $\psi^* > \psi$. For comparative statics, now recall the e.q(a.23) and (a.24). Instead of performing the total differentiation to the optimal conditions, one can simply conduct a thought experiment using the e.q.(a.23) and (a.24). Starting with an equilibrium situation, suppose T^* all of sudden increases. Then by e.q.(a.23), ψ^* must remain unchanged and also by e.q(a.24) κ must remain same. But by the $c(\kappa)$ function in e.q(a.24), κ must also go up which is a contradiction. Now let us suppose a_f^* falls and a_h^* rises. Then by e.q(a.23) ψ^* must increase which in turn imply a fall in κ by the e.q(a.24). Yet the $c(\kappa)$ function in e.q(a.24) again forces κ to increase, which contradicts the fall in κ by the e.q(a.24). Therefore these thought experiments leaves us with nothing but $\partial a_f^*/\partial T^* > 0$ and $\partial \psi^*/\partial T^* < 0$. Having the effects of ΔT^* on ψ^* and a_f^* established, one can further pursue the same experiments with the a_h^* and κ. Since $\partial \psi^*/\partial T^* < 0$ for sure, the e.q(a.24) also makes κ rise in response to the increase in κ. Consequently, the increase in κ and the $c(\kappa)$ function in the e.q(a.24) also forces a_h^* to go up in equilibrium as κ goes up. To sum up, it must be also true that in equilibrium $\partial a_h^*/\partial T^* > 0$ and $\partial \kappa/\partial T^* > 0$.

When $T^* < \check{a}$

it is easily understood why both ψ^* and ψ exceed the β in equilibrium. For the $\psi^* > \psi$ in equilibrium, one could simply recall the e.q(a.31) and the optimal condition for the home asset holdings by the home agent in Lemma 6 as:

$$\psi - \beta = \sigma\beta \left\{ u'(\beta T) - 1 \right\},$$
$$\psi^* - \beta = \sigma \left\{ u'(\beta(T^* - a_h^*)) - 1 \right\}.$$

Since $\beta T^* > \beta(T^* - a_h^*)$ when $a_h^* \in (0, T^*)$, $\psi^* > \psi$ must hold in equilibrium. For comparative statics, the exactly same kind of experiments in the preceding case could be conducted. Recall the e.q(a.31) and (a.32). Let us imagine a situation where κ rises from the initial steady state. Suppose $\Delta a_f^* = 0$ and a_h^* goes up in response. Then by the e.q(a.31), $\partial \psi^*/\partial T^* = 0$ ad by the e.q(a.32), $\partial \kappa/\partial T^* < 0$. But these would mean in accordance with the $c(\kappa)$ function in the e.q(a.32) that a_h^* must fall which is a contradiction. Now suppose a_f^* goes up and a_h^* decreases instead. Then by the same cost function, κ must increase and at the same time ψ^* should fall. However by the e.q(a.31) the ψ^* must rise so again the contradiction arises. Hence $\partial a_f^*/\partial T^* > 0$ and $\partial \psi^*/\partial T^* < 0$ must be true just like the preceding example. Nevertheless the effects of ΔT^* on the κ and a_h^* are this time ambiguous. The e.q(a.32) reveals that given the increase in κ the rise in a_f^* and the fall in ψ^* can not guarantee the signs of $\partial a_h^*/\partial T^*$ and $\partial \kappa/\partial T^*$. Basically this has been caused by the effect of the terms inside the square bracket in the RHS of e.q(a.32), i.e., $(1-\sigma)+\sigma u'(\beta T^*)$, which generates additional downward pressure for the expected surplus from carrying the asset in the case of rising κ. Therefore without this term, this thought experiment would have resulted in exactly same results as the preceding case especially the $\partial a_h^*/\partial T^* > 0$

and $\partial\kappa/\partial T^* > 0$. But since this term is present, the upward pressure for the a_h^* would be somewhat mitigated. Depending on the parameter values, the precise effect would vary. At least though it is obvious that the positive effect of κ changes on the a_h^* in this scarce κ case is smaller than the one in the less scarce case of $\check{a} < T^* \leq \check{a} + c(\tilde{\kappa})/\beta$.

Next, we provide proofs for the effects of χ_h on the various equilibrium objects. An easy proof could be done by a similar thought experiment as in Proposition 1. Recall the e.q(a.31) and (a.32). Suppose χ_h increases and as a result ψ^* remains same and κ goes up. Then by the cost function in e.q(a.32), it must be true that a_h^* rises while a_f^* falls. But then since a_f^* falls the e.q(a.31) implies an increase in ψ^* which is a contradiction. Now suppose κ remains same while ψ^* increases but this generates an immediate contradiction from the e.q(a.32). Next suppose the κ falls down and ψ^* increases instead. But again from the cost function, a_h^* must decrease which would automatically imply an increase in the level of a_f^* by the market clearing condition. This combined with the e.q(a.31) would simply mean a fall in the equilibrium level of ψ^* which is again a contradiction. Lastly now suppose χ_h increases along with κ and ψ^*. Then since κ goes up it is easily understood that a_h^* increases while a_f^* falls from the cost function. Again since a_f^* falls the e.q(a.31) implies an increase in ψ^* which is consistent with the assumption. This completes the proof. *Q.E.D*

Figure 1: Aggregate Trends for International Reserves & OTC Inflows

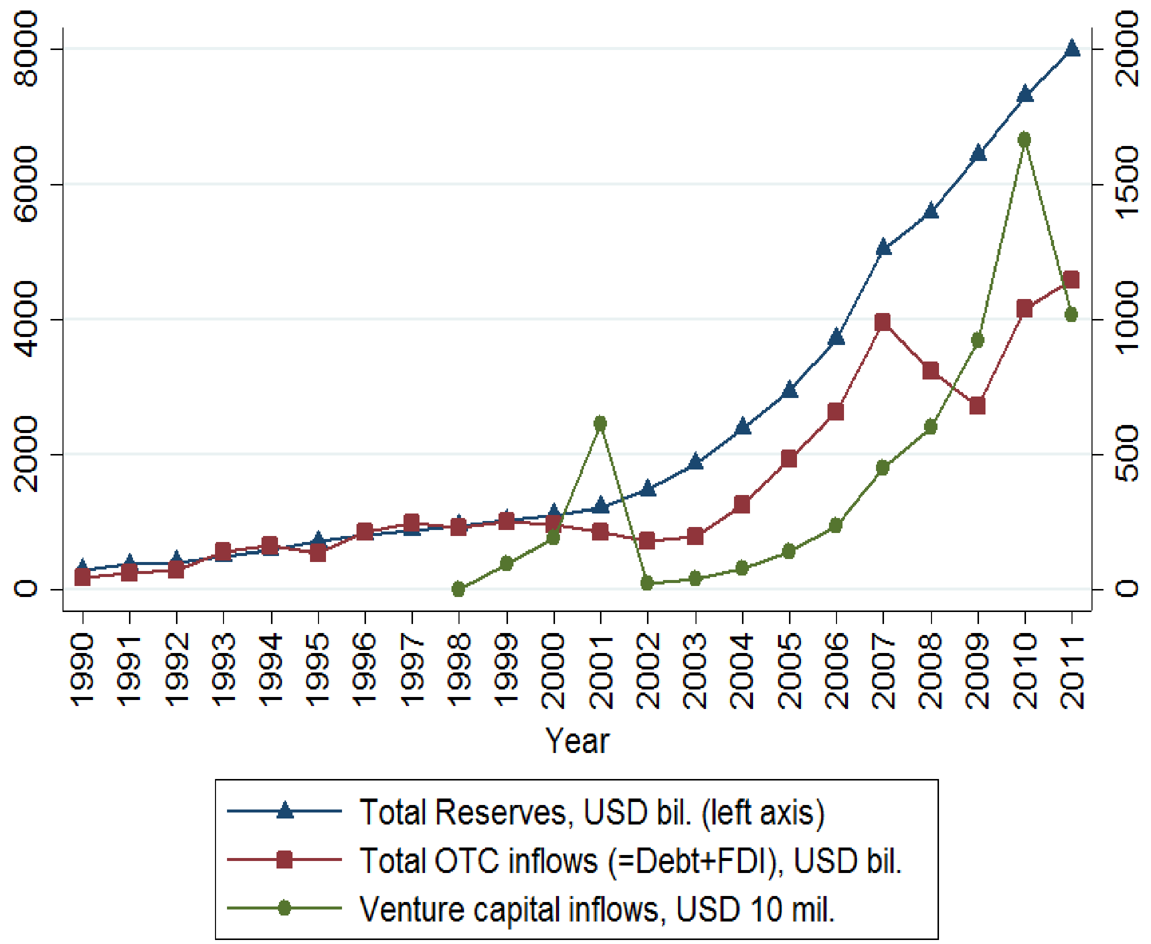

Figure 2: Timing of Events

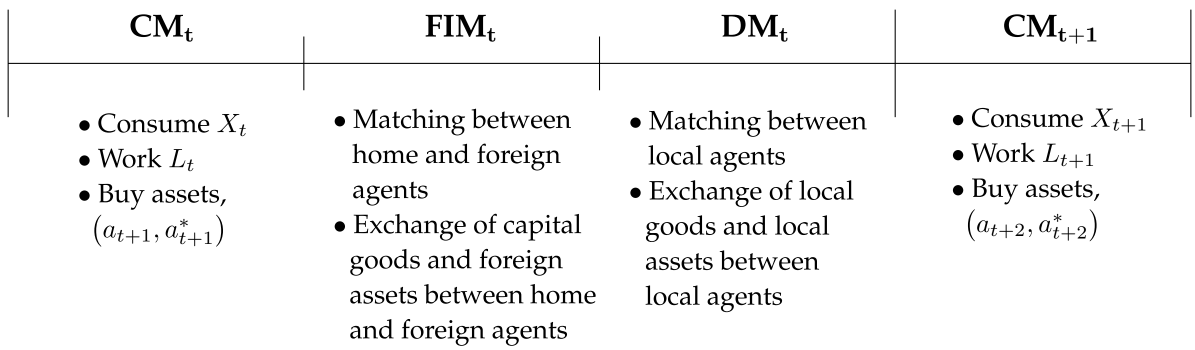

Figure 3: Regions of the FIM Bargaining Solution

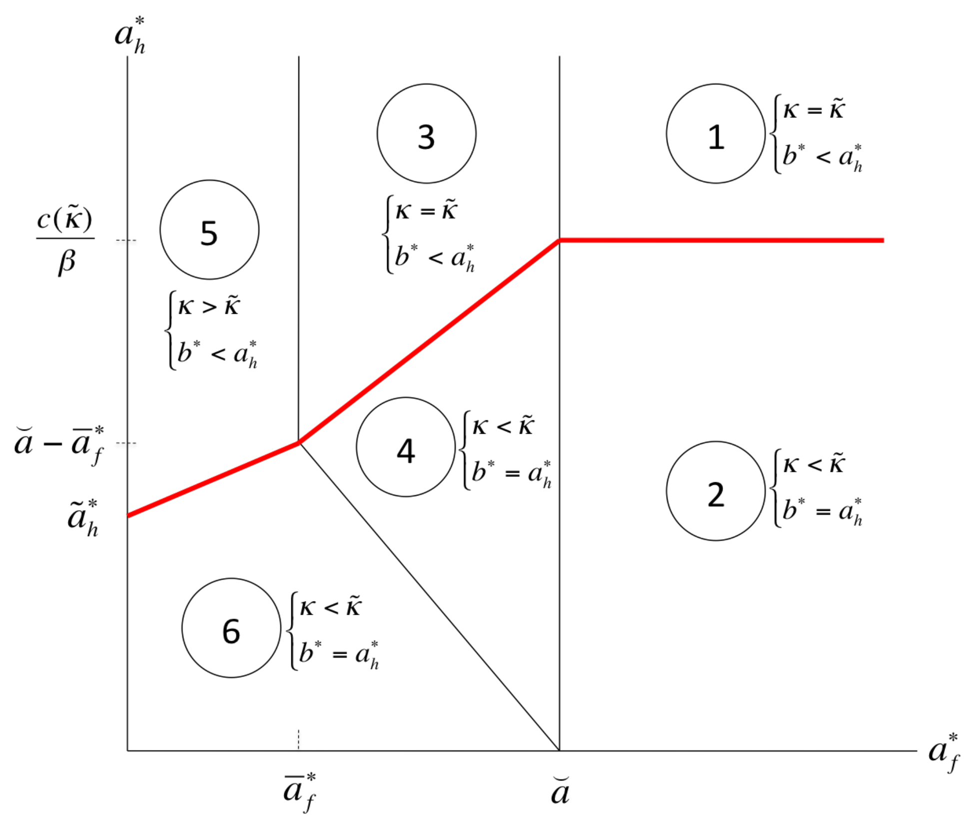

Figure 4: Home Agent's Foreign Asset Demand Given Different Levels of $\widehat{a}_f^*$

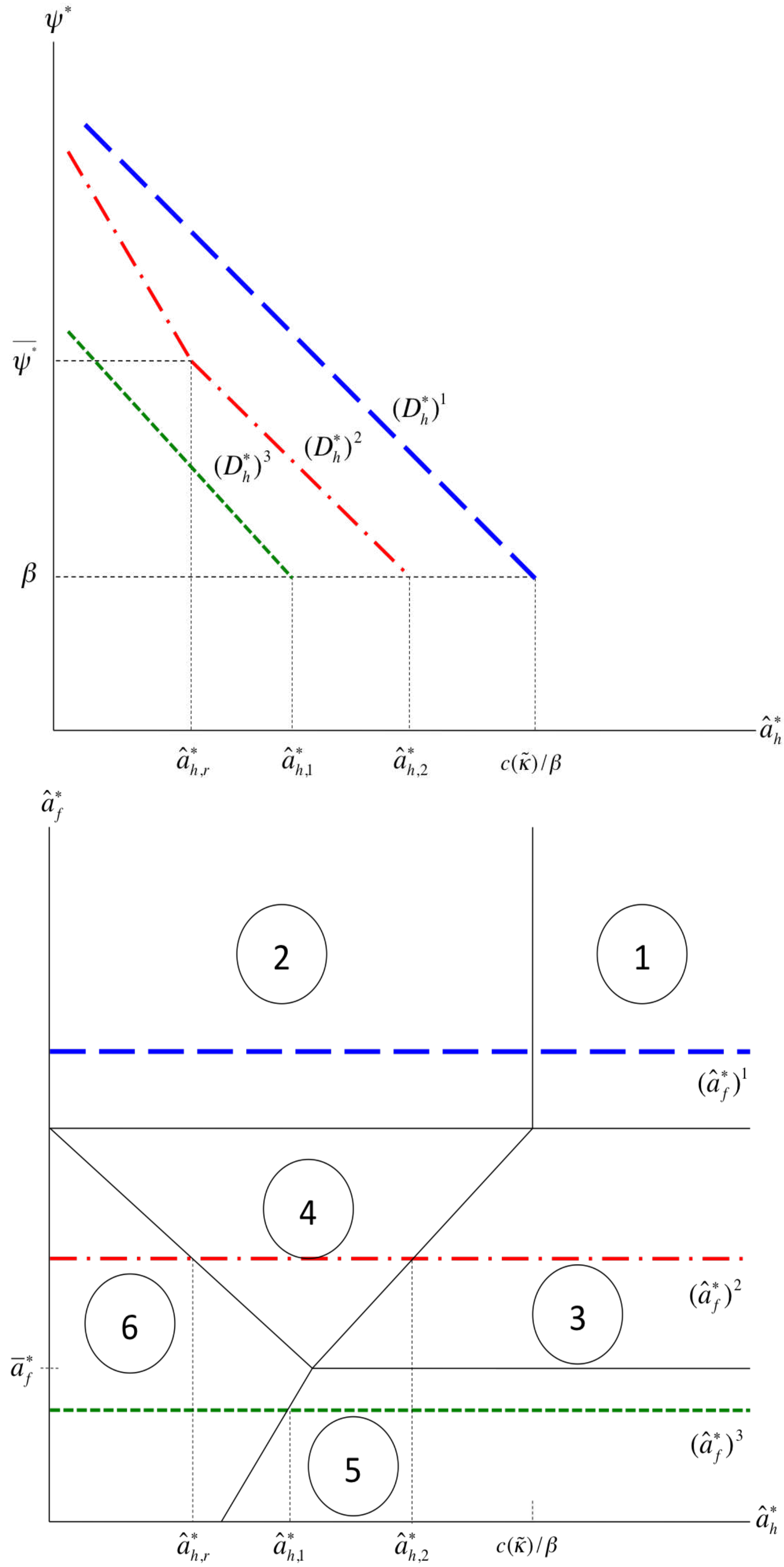

Figure 5: Aggregate Regions of (a_h^*, a_f^*) in Equilibrium

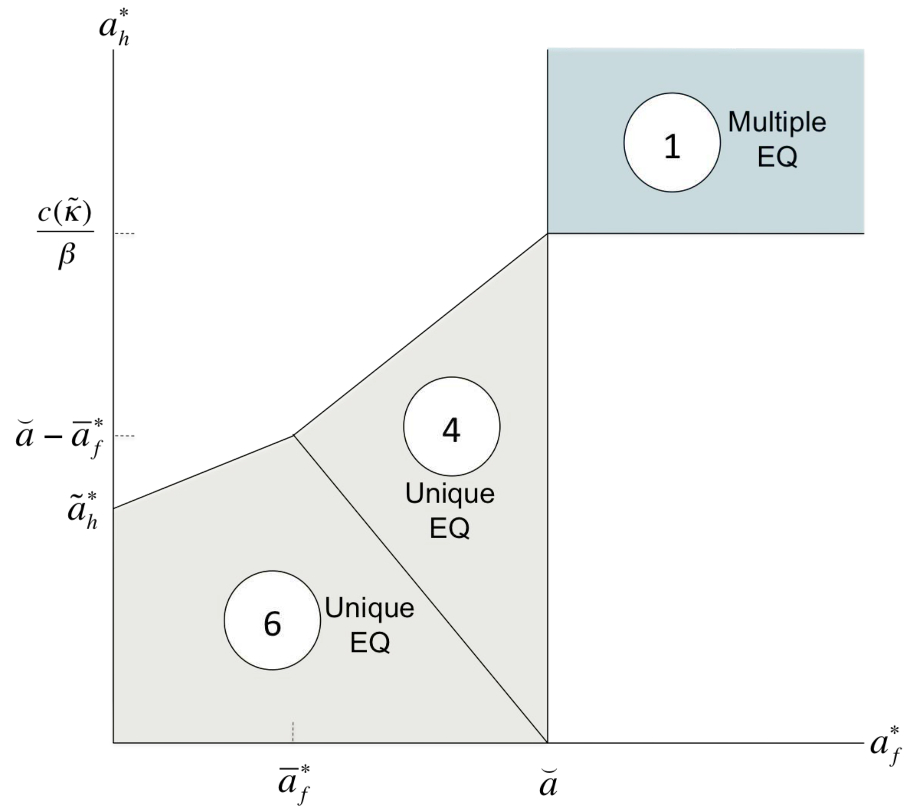

Figure 6: Regions of the FIM Bargaining Solution $(\beta\breve{a} + \sigma\,[u(\tilde{q}) - \tilde{q}] \leq c(\tilde{\kappa}))$

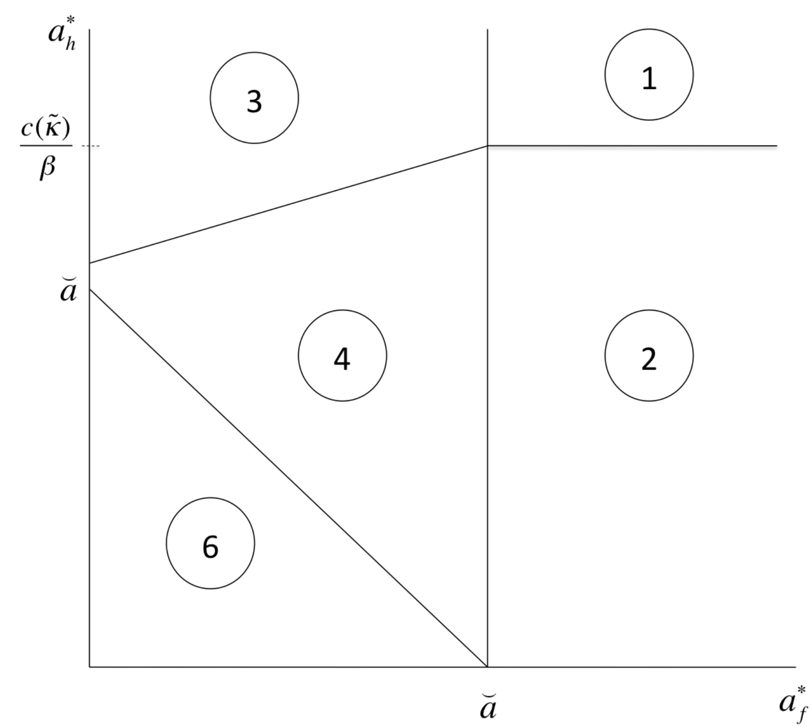

Table 1: **Countries Included in the Sample**

East and Central Asia	
Bangladesh	Malaysia*
Cambodia	Mongolia
China, P.R.: Mainland*	Nepal
China: Hong Kong S.A.R.*	Pakistan
India*	Philippines*
Indonesia*	Singapore*
Korea, Rep.*	Sri Lanka
Kazakhstan	Tajikistan
Kyrgyz Republic	Thailand*
Lao People's Dem. Rep.	Vietnam
Oil-producing countries	
Algeria	Lebanon
Bahrain	Libya
Jordan	Morocco
Egypt	Oman
Israel*	Saudi Arabia
Kuwait	Tunisia
Latin America	
Argentina*	Honduras
Bolivia	Mexico*
Brazil*	Nicaragua
Chile*	Panama*
Colombia*	Paraguay
Costa Rica	Peru*
Dominican Republic	Uruguay
El Salvador	Venezuela, Rep.*
Guatemala	
East Europe & Others	
Albania	Latvia
Armenia	Lithuania
Belarus	Macedonia
Bosnia and Herzegovina	Poland*
Bulgaria	Romania
Croatia*	Russia*
Czech Republic	Slovak Republic
Estonia	Slovenia
Georgia	South Africa*
Moldova	Turkey
Hungary*	Ukraine

* indicates countries that private venture capital data are available

Table 2: **Summary Statistics**

Variables	Observations	Mean	Std. Dev
Reserves/GDP	1371	0.173	0.164
OTC inflows(Debt+FDI)	1371	0.046	0.058
OTC inflows(Debt only)	1371	0.041	0.054
Venture capital	144	0.108	0.417
Financial openness ($defacto$)	1371	1.95	3.515
Financial openness ($dejure$)	1341	0.344	0.475
(log) Population	1371	16.490	1.546
(log) GDP per capita	1371	8.869	0.902
M2/GDP	1371	0.502	0.379
Trade openness (Import to GDP)	1371	0.461	0.287
(log) Terms of trade	1371	4.621	0.211
Exchange rate volatility	1371	0.026	0.081
Peg	1371	0.295	0.456
Soft peg	1371	0.344	0.475
Currency crisis	1371	0.026	0.158
Banking crisis	1371	0.102	0.303

Table 3: **Benchmark results, OTC Inflows and Reserves/GDP**

Simultaneous Equations Model (3SLS)				
	(1)	(2)	(3)	(4)
Dependent Var.	OTC Inflows	OTC Inflows	Venture Capital Inflows	Venture Capital Inflows
Reserves/GDP	0.2629***	0.2835***	0.9032***	0.6047***
	(0.0084)	(0.0082)	(0.1416)	(0.1049)
Financial Openness	0.0017***		0.0032	
	(0.0004)		(0.0023)	
Dependent Var.	Reserves/GDP			
OTC or Venture Capital Inflows	2.7264***	2.2591***	0.9051***	0.1912***
	(0.0787)	(0.0825)	(0.0830)	(0.0594)
Financial Openness		0.0081***		0.0379***
		(0.0010)		(0.0023)
Observations	1,519	1,519	160	160

Standard errors are in parentheses. Country fixed effects, year fixed effects and crisis dummies are included but not reported

* significant at 10%; ** significant at 5%; ***significant at 1%

Table 4: **Main results, A Full System of Equations**

	Simultaneous Equations Model (3SLS)		
	(1)	(2)	(3)
Dependent var.		OTC Inflows	
Reserves/GDP	0.1496***	0.1855***	0.1538***
	(0.0114)	(0.0105)	(0.0113)
Financial openness	0.0025***		0.0026***
	(0.0005)		(0.0005)
ln_Pop.	-0.0054***	-0.0067***	-0.0054***
	(0.0010)	(0.0010)	(0.0010)
ln_GDPcap	-0.0009	-0.0004	-0.0013
	(0.0018)	(0.0018)	(0.0018)
R^2	0.208	0.169	0.205
Dependent var.		Reserves/GDP	
OTC Inflows	0.3828***	0.4842***	0.4538***
	(0.0902)	(0.0890)	(0.0881)
Financial Openness	0.0013	0.0022**	
	(0.0010)	(0.0010)	
ln_Pop.	0.0143***	0.0150***	0.0142***
	(0.0022)	(0.0022)	(0.0022)
ln_GDPcap	0.0262***	0.0251***	0.0268***
	(0.0036)	(0.0036)	(0.0035)
M2/GDP	0.1539***	0.1486***	0.1544***
	(0.0099)	(0.0097)	(0.0097)
Trade openness	0.2438***	0.2355***	0.2446***
	(0.0152)	(0.0151)	(0.0150)
ln_TOT	0.1108***	0.1070***	0.1090***
	(0.0130)	(0.0128)	(0.0129)
Exchange rate_volatility	-0.0449	-0.0433	-0.0418
	(0.0337)	(0.0333)	(0.0336)
Peg	-0.0124*	-0.0120*	-0.0119*
	(0.0072)	(0.0071)	(0.0072)
Soft peg	0.0092	0.0088	0.0088
	(0.0065)	(0.0064)	(0.0065)
R^2	0.622	0.615	0.617
Observations	1,371	1,371	1,371

Standard errors are in parentheses.*** p<0.01, ** p<0.05, * p<0.1
Country fixed effects, year fixed effects and crisis dummies
are included but not reported

Table 5: **Robustness Check I, Alternative Financial Openness (Chinn-Ito 2008)**

Simultaneous Equations Model (3SLS)			
	(1)	(2)	(3)
Dependent var.		OTC Inflows	
Reserves/GDP	0.1741***	0.1780***	0.1748***
	(0.0106)	(0.0106)	(0.0106)
Financial Openness (Chinn-Ito)	0.0033***		0.0033***
	(0.0012)		(0.0012)
ln_Pop	-0.0059***	-0.0070***	-0.0059***
	(0.0011)	(0.0010)	(0.0011)
ln_GDPcap	-0.0016	-0.0001	-0.0017
	(0.0020)	(0.0019)	(0.0020)
R^2	0.181	0.174	0.181
Dependent var.		Reserves/GDP	
OTC Inflows	0.3918***	0.3999***	0.3996***
	(0.0893)	(0.0892)	(0.0885)
Financial Openness (Chinn-Ito)	0.0001	0.0014	
	(0.0012)	(0.0023)	
ln_Pop	0.0144***	0.0148***	0.0144***
	(0.0024)	(0.0024)	(0.0023)
ln_GDPcap	0.0273***	0.0265***	0.0272***
	(0.0038)	(0.0037)	(0.0036)
M2/GDP	0.1549***	0.1544***	0.1546***
	(0.0098)	(0.0098)	(0.0098)
Trade Openness	0.2542***	0.2534***	0.2538***
	(0.0152)	(0.0152)	(0.0152)
ln_TOT	0.1121***	0.1118***	0.1119***
	(0.0132)	(0.0132)	(0.0132)
Exchange rate_volatility	-0.0317	-0.0316	-0.0317
	(0.0352)	(0.0352)	(0.0350)
Peg	-0.0131*	-0.0131*	-0.0131*
	(0.0074)	(0.0073)	(0.0073)
Soft peg	0.0075	0.0074	0.0074
	(0.0067)	(0.0067)	(0.0066)
R^2	0.621	0.620	0.620
Observations	1,341	1,341	1,341

Standard errors are in parentheses.*** p<0.01, ** p<0.05, * p<0.1
Country fixed effects, Year fixed effects and Crisis dummy
are included but not reported

Table 6: **Robustness Check II, Direct OTC measure, Venture capital**

	Simultaneous Equations Model (3SLS)		
	(1)	(2)	(3)
Dependent var.	OTC Inflows: Private Venture Capital		
Reserves/GDP	1.0567***	0.4883***	0.9922***
	(0.3578)	(0.1578)	(0.3523)
Financial Openness	-0.0301*		-0.0258
	(0.0169)		(0.0166)
ln_Pop	-0.0180	0.0089	-0.0147
	(0.0346)	(0.0311)	(0.0345)
ln_GDPcap	0.0263	0.0517	0.0248
	(0.0884)	(0.0872)	(0.0883)
R^2	0.077	0.108	0.083
Dependent var.	Reserves/GDP		
Venture Capital Inflows	0.1272***	0.1304***	0.1463***
	(0.0253)	(0.0252)	(0.0250)
Financial Openness	0.0104**	0.0090*	
	(0.0048)	(0.0047)	
ln_Pop	0.0453***	0.0452***	0.0469***
	(0.0066)	(0.0066)	(0.0067)
ln_GDPcap	0.0921***	0.0938***	0.0940***
	(0.0172)	(0.0172)	(0.0176)
M2/GDP	0.0555**	0.0573***	0.0649***
	(0.0222)	(0.0221)	(0.0221)
Trade Openness	0.2544***	0.2627***	0.3514***
	(0.0515)	(0.0512)	(0.0255)
ln_TOT	0.0018	0.0018	0.0196
	(0.0315)	(0.0315)	(0.0310)
Exchange rate volatility	-1.0167**	-1.0500**	-1.2063***
	(0.4416)	(0.4406)	(0.4398)
Peg	0.0168	0.0174	0.0033
	(0.0301)	(0.0300)	(0.0300)
Soft peg	0.0453**	0.0468**	0.0411**
	(0.0183)	(0.0183)	(0.0185)
R^2	0.910	0.909	0.902
Observations	145	145	145

Standard errors are in parentheses.*** p<0.01, ** p<0.05, * p<0.1
Country fixed effects, year fixed effects and crisis dummies
are included but not reported

Table 7: **Robustness Check III, Another OTC measure**

	Simultaneous Equations Model (3SLS)		
	(1)	(2)	(3)
Dependent var.	OTC Inflows: Debt liability only		
Reserves/GDP	0.1746***	0.1991***	0.1768***
	(0.0104)	(0.0095)	(0.0103)
Financial Openness	0.0016***		0.0017***
	(0.0005)		(0.0004)
ln_Pop	-0.0059***	-0.0067***	-0.0059***
	(0.0009)	(0.0009)	(0.0009)
ln_GDPcap	-0.0059***	-0.0056***	-0.0062***
	(0.0017)	(0.0017)	(0.0017)
R^2	0.210	0.182	0.208
Dependent var.	Reserves/GDP		
OTC Inflows	0.6353***	0.7244***	0.6875***
	(0.0936)	(0.0922)	(0.0924)
Financial Openness	0.0012	0.0020**	
	(0.0010)	(0.0010)	
ln_Pop	0.0150***	0.0156***	0.0148***
	(0.0022)	(0.0022)	(0.0022)
ln_GDPcap	0.0279***	0.0275***	0.0289***
	(0.0035)	(0.0035)	(0.0035)
M2/GDP	0.1469***	0.1418***	0.1475***
	(0.0097)	(0.0096)	(0.0095)
Trade Openness	0.2263***	0.2184***	0.2275***
	(0.0156)	(0.0154)	(0.0153)
ln_TOT	0.1041***	0.1005***	0.1027***
	(0.0129)	(0.0127)	(0.0128)
Exchange rate volatility	-0.0407	-0.0393	-0.0382
	(0.0332)	(0.0327)	(0.0330)
Peg	-0.0118*	-0.0114	-0.0113
	(0.0071)	(0.0070)	(0.0071)
Soft peg	0.0085	0.0082	0.0082
	(0.0064)	(0.0063)	(0.0064)
R^2	0.614	0.606	0.609
Observations	1,371	1,371	1,371

Standard errors are in parentheses.*** p<0.01, ** p<0.05, * p<0.1
Country fixed effects, year fixed effects and crisis dummies are included but not reported