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Network Effects in Currency Internationalisation: Insights from BIS Triennial Surveys and Implications for the Renminbi*

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Abstract

The dominance of the US dollar in foreign exchange (FX) markets appears to reflect very strong network effects in the use of international currencies. What we observe today is the result of a slow-moving process that has witnessed a switch from the dominance of the pound sterling to the US dollar, perhaps during the interwar period in the early part of the 20th century. This paper presents a discrete choice model of FX trading that explicitly allows for this type of critical transitions in order to understand the dynamics of currency turnover in FX markets. We estimate the model using the Bank for International Settlements' data from triennial surveys of FX markets and also examine the factors that could potentially shift the dynamic path and lead to an earlier critical transition. We then discuss the implications for the renminbi, a budding international currency. If the renminbi were to become a dominant international currency, it would require China to attain a much higher level of financial development and openness. It is important to note that our model does not address the possibility of a gradual weakening of the network effects in FX markets due to, for example, the advancement of trading technologies, which would allow the co-existence of a few equally dominant major currencies.

Keywords: Foreign Exchange, International Currency, Network Effects, Financial Development, Renminbi, Critical Transition

JEL Classifications: F31, F33, G12, O53

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1. Introduction

The international monetary system has been dominated by one national currency that acts as the main medium of exchange, unit of account, and store of value. The Dutch guilder was the prominent international currency in the 17th and 18th centuries, and then pound sterling played the role until World War I. The US dollar has been dominant perhaps since the interwar period (Eichengreen and Flandreau, 2009; Eichengreen, 2011; Prasad, 2014; Schenk, 2010).

A snapshot of the dominance of the US dollar is shown in Figure 1, which contrasts the turnover share of currencies in FX markets against the global trade share of the issuing countries. All points would lie along the 45-degree line, were FX transactions between the currencies of the two parties only to reflect the use of the currency for bilateral trade. The actual trading of the US dollar is far greater than what would be expected purely on the basis of direct trade flows with the US. Substantial systematic residual biases, which are positive and large for the US dollar, are left as unexplained by a linear regression model of the currency turnover share even when controlling for more determinant factors (Figure 2).

Why do one or a few currencies dominate the international monetary system? What explains the nonlinear relation between currency internationalisation and underlying fundamentals? With the emergence of China as a major economic power, does the renminbi have the potential to become a major international currency, and if so, what would the dynamic path look like? The answers to these questions appear to have much to do with network effects in the use of money (Kindleberger, 1981; Krugman, 1980, 1984).

A fiat money derives value from others using it. In this regard, there is an analogy between money and language. What makes English the world's *lingua franca* is not its simplicity or internal beauty but its wide use (Kindleberger, 1981). Similarly, one chooses to use a currency in the belief that it is the one that others are most likely to use. Without government regulation and enforcement, the invisible hand of the market guide agents to concentrate on a limited number of currencies to deal with market frictions such as costs of transaction and calculation. There appear to be significant efficiency gains from this concentration due to economies of scale. For example, the centrality of a leading currency facilitates the functioning of the FX market through its role as a vehicle for transactions.

From a dynamic perspective, once a currency gets established as a leading currency, it is almost in a natural monopoly situation, resulting in a self-justifying dominance. Small changes in the determinants will not produce corresponding changes in the international status of a currency, at least in the short run. Evolution of the international currency system may exhibit a good deal of inertia in favour of the existing dominant currency, but once the shift occurs it will have lasting effects. As pointed out by Krugman (1984, p.268), "the choice of a vehicle currency reflects both history and hysteresis."

In this paper, we develop a simple theory of trading turnover in currency markets and explicitly model network effects and potential critical transitions. We also examine the factors that could potentially shift the dynamic path, which may advance critical transitions. We use a panel data set to estimate a dynamic model of FX turnover that is of a logistic functional form and derived from the theoretical model. The data set is created by combining the results of FX market surveys conducted every three years by the Bank for International Settlements (BIS) and country information of the surveyed currencies. The BIS triennial surveys provide comprehensive information on the size and structure of global FX markets (BIS, 2013). They cover a substantial period of time and give enough variation in the international use across currencies and over time to allow us to test our theoretical model on the data. Our empirical analysis detects strong network effects in currency use in FX markets. We also find evidence that financial depth and, in particular, bond market size of the issuing country are key determinants of the FX turnover share of a currency, along with trade share and other factors. This not only reflects the "financialisation" of currency trading (McCauley and Scatigna, 2011), but is also consistent with the historical experience of how financial development, especially the growth of the market in trade acceptances, forcefully pushed the rise of the US dollar (Eichengreen, 2011, Ch. 2).

To understand how network effects may shape the path of the renminbi going global, we then preform counterfactual analysis on the basis of the estimated model. Our quantitative exercises show that progress toward renminbi internationalisation is not likely to be linear, which is consistent with the views of, for example, Eichengreen and Kawai (2014) and He (2014). Instead, it may entail a period of gradual adjustment until possibly arriving at a critical point. Financial deepening in China, especially development of the fixed income markets, will help to create a level effect that increases the volume of renminbi trading and also induce a structural effect that shifts the transition path.

This paper is in six sections. Section 2 outlines a theoretical model of currency turnover with network effects. Section 3 gives a brief overview of FX markets and the BIS survey data. Section 4 presents our estimates of the model. Section 5 takes a tentative look forward on the international role of the renminbi. The final section concludes with a discussion of possible extensions. More quantitative experiments, as well as a detailed description of the model and data, are available in the appendices.

2. A Stylized Model of Currency Turnover

2.1 Environment

We sketch a discrete choice model of the FX market that incorporates network effects in the spirit of Brock and Durlauf (2001). Our focus is on the intuition behind the model behaviour. Technical derivations and results can be found in Appendix A.

There are J currencies traded in the FX market. A population of I_j *ex ante* identical traders specialize in trading currency j, who represent individual and institutional customers, banks, brokers, other financial institutions and central banks. A trading opportunity of the same normalized size comes to each trader at the beginning of each period. The currency, which is other than j, on one side of the potential transaction is randomly given. Each trader, $i \in I_j$, must choose a binary action c_{jt}^i regarding whether or not to execute the transaction against currency j, which is coded as 1 and -1 respectively.[1] Transactions for other currencies are organized in the same way.

The payoff of a trader not only depends on his own choice, but is also a function of the choices of others in the same market because of network effects. This is intended to capture the efficiency gains arising from the use of a (vehicle) currency with wide acceptance. If the currency has a deep and liquid market, the transaction costs will be low and the options to hedge risks will most likely to be available. Like choosing a currency as the language of FX trading, there are also economies of scale in knowledge development and skill acquisition that may lead to specialisation in the currency with wide usage. On the other hand, there could be gains from diversification, which seem to become more relevant due to improved trading platforms and payment infrastructures (Genberg, 2011). Nevertheless, at the current stage of technological development, network effects still appear to be strong; most of the time, an excellent command of the language spoken by most people is more useful than a knowledge of multiple languages that are rarely used.

Specifically, we assume that the payoff function Π_{jt}^i of trader i in currency j at time t consists of three additive components:

$$\Pi_{jt}^i\left(c_{jt}^i, c_{jt}^{-i}\right) = \phi_{jt} c_{jt}^i + \rho c_{jt}^i E(m_{jt}) + \xi\left(c_{jt}^i\right), \quad (1)$$

where $E(m_{jt})$ is the expected average of the choices of all traders in currency j at time t. The coefficient ϕ_{jt} on the first term captures the direct benefit from trading currency j, which depends on the intrinsic characteristics of the currency and the economic conditions of the issuing country. The multiplicative interaction between individual and expected average choices in the second term describes a case of proportional spillovers, i.e., the payoff is linear in the mean decision level, given the trader's own choice. We assume that the coefficient $\rho > 0$ is the same over time and across currencies. Parameter ρ then measures the degree of network effects in the trading of currencies.

The last term of (1), $\xi(c_{jt}^i)$, is an independently and identically distributed random payoff component. This is intended to capture factors not reflected in the first two deterministic terms and is essential for *ex ante* identical agents to make heterogeneous choices *ex post*. We assume that the errors $\xi(-1)$ and $\xi(1)$ are independent and extreme value distributed so that the difference between them is logistically distributed,

[1] The support of the binary action is set to be $\{-1,1\}$ instead of $\{0,1\}$, which is typically used in discrete choice models. This is for an analytical characterisation of equilibrium behaviour. The model can be represented using the conventional $\{0,1\}$ normalization, with all results and intuitions still following, as we will do later for empirical implementation.

$$\Pr(\xi(-1) - \xi(1) \leq a) = \frac{1}{1 + \exp(-\theta a)}, \qquad \theta \geq 0, \tag{2}$$

where θ is a scale variable proportional to the inverse of the standard deviation. This specification of the distribution will allow us to solve the model analytically.

Finally, we impose a simple mechanism of expectations formation,

$$E(m_{jt}) = m_{jt-1}. \tag{3}$$

Traders use last period's average choice to approximate the expected mean behaviour in current period. This type of expectations is myopic. While the analysis can certainly be extended to incorporate more sophisticated expectations, the present assumption is convenient in terms of econometric modelling.

The timing of the decision process is as follows: First, traders observe currency characteristics ϕ_{jt} and previous trading behaviour m_{jt-1}, and use m_{jt-1} to forecast the average choice of the market. Then, the stochastic payoff component is realised for each trader, and hence the entire payoff function is known. Finally, traders compare the payoffs of 1 and -1 according to their realised payoff function and make decision simultaneously. This leads to heterogeneous choices in the market so that the share of trading can be defined.

2.2 Steady State Equilibrium

Traders solve their problems in a discretionary fashion, taking others' and previous average choices as given. Trader i's optimal decision is to execute the trading opportunity, $c_{jt}^i = 1$, if $\Pi_{jt}^i\left(1, c_{jt}^{-i}\right) > \Pi_{jt}^i\left(-1, c_{jt}^{-i}\right)$, and not to execute otherwise. Under assumptions (1)-(3), the *ex ante* probabilities for $c_{jt}^i = 1$ and that $c_{jt}^i = -1$ can be solved explicitly, which correspond to the fractions of traders in the population I_j who choose to trade currency *j* and those who choose not to. The average choice m_{jt} then follows as a hyperbolic function of m_{jt-1},[2]

$$m_{jt} = \tanh\left[\theta\left(\phi_{jt} + \rho m_{jt-1}\right)\right]. \tag{4}$$

This equation of motion for m_j is of the main interest to us, and several comments are in order. First, it is clear that currency j will be widely traded if its intrinsic attractiveness ϕ_{jt} is high and if it has already been widely traded, i.e. m_{jt-1} is high. Second, the degree of network effects ρ determines the curvature of the S-shaped $tanh$ function, whereas the intrinsic attractiveness ϕ_{jt} acts as a shift

[2] See Appendix A for detailed derivations.

parameter. In the absence of network effects, $\rho = 0$, currency trading will depend only on the characteristics of the currency itself and there will be no inertia in favour of the established currency. Additionally, our results are about the average choice m_j, but it is easy to represent them in terms of the proportion y_{jt} of traders who choose to trade, given that

$$m_{jt} = 2y_{jt} - 1. \tag{5}$$

Intuitively, the average choice between -1 and 1 is greater than zero if more than half of the traders choose 1.[3]

When fundamental factors ϕ_{jt} are held time invariant as ϕ_j, we can characterise the average choice m_j^* in steady state equilibrium, which is defined as

$$m_j^* = \tanh\left[\theta\left(\phi_j + \rho m_j^*\right)\right]. \tag{6}$$

Graphically, if we draw m_{jt} against m_{jt-1}, steady state equilibrium is an intersection between the 45-degree line and the $tanh$ dynamic function. This allows us to illustrate the interaction between economic fundamentals and network effects in currency internationalisation intuitively.

Figure 3 represents the case in which network effects are weak. Trading decisions are then mainly driven by the intrinsic attractiveness of the currency. Although random shocks disturb individual choices, the average choice is uniquely given by the profitability of trading opportunities as reflected in the deterministic component. Thus, there is only one steady state equilibrium. As fundamental conditions change (ϕ_j increases or decreases), the $tanh$ reaction function is shifted (left or right) and the equilibrium average choice will move correspondingly.

Multiple steady state equilibria may emerge when network effects are strong enough. The solid line in Figure 4 shows the reaction function when $\phi_j = 0$. In this baseline situation, it makes no difference to trade or not according to the intrinsic attractiveness of the currency. However, since network effects are strong, a trader tends to follow the behaviour of others. In an average sense, if others choose to trade, then it is optimal to trade; if others choose not to trade, then don't trade; and if half trade and don't, then the decision about whether to trade or not carries equal probability.[4] Network effects induce sufficient curvature for the $tanh$ dynamic function so that it crosses the 45-degree line three times. Thus, there are three steady state equilibria: one involves a high trading volume of the currency; one involves a low trading volume; and one is between the two. In addition, the high- and low-trade

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[3] y_{jt} also corresponds to the probability of trading and the average choice in the conventional presentation with the binary choice set being $\{0,1\}$.

[4] The random component in the payoff function (2) is such that each option will be taken by some traders with a probability greater than zero. Thus, we have to think about the average or majority of choices of traders.

steady state equilibria are locally stable, while the mixed one is locally unstable.

A positive (negative) intrinsic value of trading will shift the hyperbolic reaction curve left (right). As exhibited in Figure 4, a marginal trading profit will reduce the probability of not trading in the low-trade equilibrium, requiring a larger proportion of individuals not trading to maintain the indifference between trading and not trading in the mixed equilibrium, and reinforcing the high-trade equilibrium, all relative to the baseline case. Still, the intrinsic attractiveness of the currency is not enough to resist the inertia generated by network effects, and multiple equilibria remain. If the economy is initially in the low-trade equilibrium, however, a smaller shock that causes the average choice to jump beyond the mixed equilibrium will be able to shift the economy to the high-trade steady state equilibrium.

In Figure 5, the fundamental factors become strong enough to overcome network effects so that a trader tends to trade anyway even if all others chose not to trade. The high-trade equilibrium becomes the unique equilibrium.[5] A fundamental abrupt change from multiple equilibria to unique equilibrium materializes at the tangent point between the dash line and the 45-degree line, which we refer to as a "critical point." Suppose the economy is in the low-trade steady state equilibrium. As the fundamental conditions reach the threshold, all traders suddenly realize that the high-trade equilibrium is the only steady state equilibrium given exogenous factors, and this change of their behaviour leads the economy to converge to this new equilibrium fast. Thus, a "critical transition" describes the structural change of the trading system from multiple steady state equilibria to unique equilibrium, and beyond the critical point, system converges to the high-trade steady state equilibrium along a new dynamic path (if it does not shift any more). Figure 6 illustrates the dynamic adjustment toward the high-trade steady state equilibrium over time after the critical transition.

In short, coordinated behaviour among traders may induce a multiplicity of steady state equilibrium, while critical transitions only occur when the accumulation of favourable fundamental forces overcomes the persistence of the network effects.

The full dynamics of m_{jt} has to allow ϕ_{jt} to evolve over time. A change of ϕ_{jt} generates two different types of effects. On the one hand, it exerts a direct impact on the traders' current decisions and hence the average choice m_{jt}, following equation (4). This is a level effect. On the other hand, the change shifts the hyperbolic reaction function, which leads to structural changes in the market. For example, as shown in the Figure 4, when the fundamental attractiveness of currency j increases, the two stable steady state equilibria shift toward more trade in this currency, while the unstable mixed equilibrium demands less trade. A smaller shock such that m_{jt} jumps from the low-trade equilibrium over the mixed equilibrium will lead the economy to converge to the high-trade equilibrium. In other words, as currency j becomes more attractive, a shift to an equilibrium in which the currency is widely traded

[5] Although there is only one equilibrium in both Figures 3 and 5 (dot line), the mechanisms behind are different. In the first case, network effects are not strong enough to generate multiple equilibria. In the latter case, there may be network effects, but they are offset by the influence of economic fundamentals.

becomes more likely to occur. When the attractiveness further increases over time, a critical transition may be reached in the market as illustrated in Figure 5. In this situation, the pace toward wide trade in currency j accelerates.

2.3 Econometric Specification

To take our model to the data, recall that the dynamics of the average choice m_{jt} is given by equation (4). It would be more convenient to focus on the probability of trading y_{jt} as in standard binary choice models. We perform the change of variables by substituting (5) into (4), rearranging and taking the natural logarithm:

$$\ln\left(\frac{y_{jt}}{1-y_{jt}}\right) = 2\theta\left[\phi_{jt} + \rho\left(2y_{jt-1} - 1\right)\right]. \tag{7}$$

The intrinsic attractiveness ϕ_{jt} is a function of many underlying factors, and we assume that the relation can be represented in a linear parametric form,

$$\phi_{jt} = b_0 + b_1 X_{jt} + \mu_j + \epsilon_{jt}, \tag{8}$$

where X_{jt} is a vector of the characteristics of currency j and its issuing country at time t, μ_j is a currency-specific but time-invariant variable, and ϵ_{jt} is an error term that is independent and identically distributed.

Using specification (8), we can rewrite equation (7) as

$$\ln\left(\frac{y_{jt}}{1-y_{jt}}\right) = \alpha + \beta y_{jt-1} + \gamma X_{jt} + u_j + \varepsilon_{jt}. \tag{9}$$

With the data on Y and X, we can estimate parameters α, β, and γ. As is standard for logistic models, the complete set of model parameters $\{b_0, b_1, \rho, \theta\}$ is not identified because θ is a common factor of α, β, and γ. We therefore proceed under the normalization of $\theta = 1$.[6]

Our model specification (9) is comparable with previous models estimated in the literature. It is standard practice in empirical work to take the logistic transformation of the outcome variable that appears as a proportion or fraction so as not to generate predictions outside the unit interval (e.g.,

[6] In this paper, we assume that θ is identical across currency and over time. It is possible to allow for currency-specific and time-varying θ_{jt} and estimate it using a second dataset on, for example, currency returns. In this case, we can identify corresponding parameters for each currency and examine how the role of network effects and fundamental conditions is shaped by the level of uncertainty associated with stochastic payoff. The extension greatly depends on how we estimate θ_{jt} (e.g., it may not necessarily correspond to the volatility in currency return), and we plan to leave it for future research. We thank Torsten Ehlers for helpful discussion on this point.

Chinn and Frankel, 2007, 2008; Lai and Yu, 2014). In particular, Chinn and Frankel (2007, 2008) implement similar cross-currency regressions of the $logit$ of currency share on a number of explanatory variables and they include the lagged $logit$ of currency share instead of the lagged currency share itself as a regressor to make their model a dynamic one. However, their regression equation is specified without much justification, while equation (9) is derived from a micro-founded model of currency turnover and allows for interesting multiple equilibria and critical transitions.

It is useful to note that the shares across currencies predicted by model (9) do not necessarily add up to unity. In principle, we can specify a system of currency-specific equations and impose the adding-up restriction. This would reflect the data-generating process better, but would render the estimation difficult given the limited number of observations. It seems that all cross-currency regression analysis, including Chinn and Frankel (2007, 2008), has the same issue. Despite this weakness, our estimated model helps illustrate the role of network effects in the rise and fall of international currencies in an explicit fashion.

3. A Brief Overview of FX Markets and BIS Central Bank Surveys

To implement estimation of the reduced form equation (9), we use data from the BIS Triennial Central Bank Surveys of turnover in FX markets. This survey has been conducted very three years since 1989, and the latest survey took place in April 2013; 53 central banks participated and data was collected from about 1,300 banks and other dealers. Turnover in spot, outright forward FX swap, currency swap and FX option transactions in 40 different currencies is reported to provide a detailed snapshot of global FX markets during the month of April.

3.1 Some Facts about FX Turnover

Before we describe variables used in the analysis, we briefly outline some basic facts about FX markets as background. The FX market is the largest financial market in the world, trading 24 hours a day. Global FX turnover averaged $5.3 trillion per day in April 2013, which was about 35% higher than the $4.0 trillion recorded in 2010 (Figure 7). FX swaps were the most actively traded instrument in 2013, accounting for 42% of all transactions, followed by spot trading, with a share of 38%.

The distribution of renminbi turnover by instrument is different to the rest of the FX market. Trading of the renminbi used to be dominated by spot transactions, followed by outright forwards (Figure 8). During the past six years, however, the use of FX swaps, options and other products has increased greatly, reflecting the development of the renminbi market. As pointed out by Ehlers and Packer (2013), offshore trading has been a key driver of changes in the size and composition of turnover in emerging market currencies, including the renminbi, in recent years.

Trading in FX markets was dominated by financial institutions other than reporting dealers in April 2013 (Figure 9), which reflects the trend of currency trading to become more financial (McCauley and Scatigna, 2011). These non-dealer financial institutions, including smaller banks, institutional investors, hedge funds, and proprietary trading firms, as well as official sector financial institutions, are very heterogeneous in their trading motives, patterns and horizons. The share of inter-dealer trading in global FX transactions stood at 39% in 2013. FX transactions with non-financial costumers, including corporations, governments and high net worth individuals, accounted for merely 9% of global turnover.

In China, however, dealers were still the major participant in the FX market, responsible for 44% of FX turnover in April 2013 (Figure 10). Banks contributed an overwhelming fraction of the turnover associated with other financial institutions. These facts are largely due to the dominance of banks, especially big state-owned banks, in China's financial system as well as the underdevelopment of derivatives markets.

FX transactions have been concentrated in a small number of global financial centres. As shown in Table 1, the vast majority of FX trading in 2013 occurred via sales desks located in the UK (41%), the US (19%), Singapore (5.7%), Japan (5.6%), and Hong Kong (4.1%). China was only 0.7% of the global FX market.[7]

Our focus is the currency distribution of FX turnover (Table 2). Since each transaction involves two currencies, the turnover shares of individual currencies add up to 200%. The US dollar was the most traded currency in April 2013, and was on one side of 87% of all FX trades. Other actively traded currencies were the euro (33%), Japanese yen (23%), pound sterling (12%), Australian dollar (8.6%), Swiss franc (5.2%), and Canadian dollar (4.6%). The Mexican peso and Chinese renminbi, as the representatives of emerging market currencies, entered the list of the top 10 most traded currencies (ranked 8 and 9, respectively). However, the structure of the FX market centred around the US dollar and a few major currencies has not changed much since 1989. This indicates persistence in the international use of currencies.

In all transactions against the renminbi, over 94% by volume had the US dollar on the other side. This ratio was higher than the average US dollar share across currency pairs. US/RMB contracts constitute over 90% of transactions involving the renminbi in all instruments, with 98% in FX swaps against the renminbi.

3.2 Variables and Data

Our main variable of interest y_{jt} is the probability of having currency j on one side of an arbitrary transaction at time t. At an aggregate level, this corresponds to the total turnover share of the

[7] The BIS triennial survey is based on sales not price-setting desks. If the data were based on price-setting desks, then concentration would be even higher. We thank Phillip Wooldridge for pointing this out to us.

currency in FX markets. This paper exploits a panel data of FX turnover shares for more than 35 currencies surveyed from 1989 to 2013 triennially that is publically available from the BIS, supplemented by unpublished data on the spot and contract trading in each currency, with additional currencies included.

To estimate (9), we need to specify fundamental determinants of FX turnover, represented by variables in vector X_{jt}. In theory, money follows trade, and one reason for the existence of FX markets is to serve international trade. Eichengreen (2011) argues that, as the US became more involved in international trade, it became increasingly inconvenient to depend on London for trade finance. The need to change resulted into a series of developments that put the US dollar on the rising path. Therefore, the FX turnover share of a currency would be expected to be associated with the share of the issuing country in world trade.

However, transaction volumes in FX markets are many times greater than the volume of trade flows.[8] McCauley and Scatigna (2011) show that as income per capita rises, currency trade become less connected to current account transactions and more likely to take place outside the home country. Market participants buy and sell FX to finance their investment operations. We use gross capital flows as a percentage of GDP to control for the financial need for FX trading. Specifically, gross capital flows are the sum of the volume of capital inflows and outflows extracted from the IMF Balance of Payments Statistics.

Cross-border flows of capital can be very volatile and involve fickle behaviour such as sudden stops and capital-account reversals (Bluedorn et al., 2013), but in any event, it depends on capital account openness. Thus, the financial openness of a country may affect the trade of its currency. In robustness checks, we replace the capital flow variable with a less volatile financial openness measure. We use a *de jure* measure, namely the Chinn-Ito index, initially constructed by Chinn and Ito (2006) and recently updated in 2013. The index is based on the binary dummy variables that codify the tabulation of restrictions on cross-border financial transactions reported in the IMF's Annual Report on Exchange Arrangements and Exchange Restrictions. Alternatively, we consider a *de facto* measure, the ratio of gross foreign assets (measured as the sum of foreign assets and foreign liabilities) to GDP, taken from the updated and extended version of a data set constructed by Lane and Milesi-Ferretti (2007).

The extent to which a currency is traded for financial purposes has to depend on the availability of investment instruments denominated in the currency or broadly, the financial depth of the issuing country. Moreover, depth is a key dimension of market liquidity. In FX markets, for example, central banks may hold foreign government bonds in their reserves and hence need to buy or sell foreign currencies to keep their positions, while institutional investors may seek opportunities in foreign equity

8 As shown in Figure 9, over 90% of trading takes places among the banks and other financial institutions, rather than with non-financial customers such as importers and exporters.

markets, generating turnover in currencies. Market makers and speculators trade securities as part of their role in FX markets. Following World Bank (2014), we measure financial depth by the size of the bond market and that of the equity market, which we include in X_{jt}. In addition, financial market liquidity (e.g. as measured by the turnover ratio in the equity market) may amplify the potential effect of financial depth on FX turnover and hence may be included in X_{jt} as well. We obtain these financial indicators from the Global Financial Development Database of the World Bank. To mitigate concern that short-term capital flows may contaminate the measurement of these financial variables, we use a one year lag of these variables in regressions.

Another potential driving force of FX turnover is expectations of exchange rate movements. If a trend depreciation or appreciation of a currency is expected, market participants react by selling or buying the currency. The literature has documented that it is challenging to explain exchange rate fluctuations with macroeconomic fundamentals, and a random walk model seems to forecast exchange rates better than economic models (Meese and Rogoff, 1983a,b). The second moment of the exchange rate may also affect currency trading under heterogeneous expectations. As argued by authors like Frankel and Froot (1990) and Jorion (1996), it takes differences among market participants to explain why they trade. Thus, there needs to be some uncertainty over the path of the exchange rate for expectations to play a role in driving transactions, but too much variation will undermine confidence and trade in the currency. We consider including both a depreciation trend and exchange rate volatility into X_{jt}. Both variables are constructed using daily data from Bloomberg.

A final consideration is the safehaven properties of a currency. To maintain the attractiveness of a currency to most market participants other than short-term arbitragers, the value of a currency should not be inflated away in the future. In other words, inflation of the currency-issuing country appears to be a relevant element of X_{jt}. Inflation data are available from the World Bank.

The Appendix B contains details about the construction of the above variables and the sources of the data, as well as descriptive statistics.

4. Empirical Analysis

4.1 Estimation Results

The model to be estimated is the dynamic relationship characterized by (9). We observe that y_{jt} is a function of u_j and hence y_{jt-1} is also a function of u_j. In other words, regressor y_{jt-1} is correlated with the error term. This renders the OLS estimator biased and inconsistent even if ε_{jt} is not serially correlated.[9] To address potential problems of endogeneity, equation (9) is estimated using a system

[9] For the fixed effects (FE) estimator, the within transformation wipes out u_j, but it induces a non-negligible correlation between the transformed lagged outcome variable and the transformed error term. When the number of time periods available is small, the FE estimator is also biased and inconsistent.

GMM estimator for dynamic panel data developed by Arellano and Bover (1995) and Blundell and Bond (1998) and implemented with *xtabond2* in Stata (Roodman, 2009).

Table 3 presents the two-step GMM estimation results of the model with different configurations of regressors. In all estimated models, the extended set of moment restrictions is not rejected by the Hansen test for over-identification. The instrument variables used in the estimation also seem appropriate.[10]

With the $logit$ of overall FX turnover share as the dependent variable, the explanatory variables discussed in Section 3.2 are introduced sequentially. Regression (1) only controls for trade and capital flows, in addition to the lagged FX turnover share.[11] It shows that FX turnover share is highly persistent, with the coefficient on the lagged term being economically high and statistically significant.[12] The share of a country in world trade has a clear positive effect on the turnover of its currency in FX markets, but the effect of gross capital flows appears insignificant. This may be because capital flows tend to be driven by short-term forces and are volatile. Indeed, since currency shares in FX trading are persistent over long time horizons, it is not difficult to understand that short-term volatilities are not important in driving such slow-moving variables.

Column (2) adds the financial variables – size and turnover in the stock market and bond market – and finds that the share of currency trade is significantly associated with the financial depth of the issuing country but not with how active the stock market is.[13] Column (3) further includes the exchange rate variables, without finding evidence for the role of the first and second moments of exchange rate movements. As argued earlier, it is generally difficult to predict the depreciation or appreciation trend. Since the effect of exchange rate volatility may be nonlinear, the heterogeneity of the currencies in the sample may have rendered the coefficient estimate insignificant. Column (4) introduces inflation as a new control variable, whose coefficient estimate is significant and negative.

Since no regression so far supports the need to control for capital flows, column (5) drops this variable. The estimates do no change much, and there is still no evidence of the significance of financial market liquidity and exchange rate movements. Omitting these variables, as shown in column (6), leaves the main findings established so far intact. We consider the empirical model displayed in column (6) as a preferred model for policy analysis.

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[10] In a number of regressions, the $m1$ test does not reject the null that there is no first-order serial correlation in the first-differenced residuals. This may be due to the fact that the dependent variable is the $logit$ of y_{jt} while y_{jt-1} appears in the right hand side of the equation. The $m2$ test does not reject the null of no second-order serial correlation.

[11] We do not include the GDP share of currency-issuing country, which is highly correlated with the trade share (the correlation is over 0.9).

[12] According to the results in Appendix A, after the change of variables, a coefficient greater than 4 on the lagged FX turnover share, i.e. $\beta > 4$, is necessary for the existence of multiple steady state equilibria.

[13] We do not include the size of financial institution in order to focus on the development of financial markets. Also, it is highly correlated with the depth of bond and equity markets.

Taken together, our regression results document strong network effects in the international use of currencies in FX markets. There is also strong evidence suggesting that the depth of a country's financial markets is a key determinant of the FX turnover share of its currency, along with trade share and inflation performance.

4.2 Robustness

Table 4 presents a set of robustness results. As shown in Table 3, short-term capital flows do not seem to be connected with currency turnover at an aggregate level. In columns (1) and (2), we use the *de facto* and *de jure* measures of financial openness in the fully controlled model instead. The *de facto* measure still appears insignificant, while the coefficient estimate on the *de jure* measure is significantly positive at the 5% level.[14] The findings on other variables remain largely the same, which gives us more confidence when focusing on the preferred model in the remaining tests.

Columns (3) and (4) consider alternative estimation methods. Since the Hausman test fails to reject the null hypothesis of random effects, column (3) reports the estimation results using the random effects model. Column (4) uses the simple pooled OLS estimator. None of the results are much different from the baseline GMM estimates in column (6) of Table 3.

Columns (5)-(7) re-estimate the preferred model using different sample periods for several reasons. First, one might worry about potential regime change associated with the introduction of the euro. Column (5) examines the model in the subsample after 2004. Second, since our data set is a combination of published data and non-published data, there may be concern about the consistency between them. Column (6) uses only the subset of published data. Finally, all previous analysis focuses on overall FX turnover share. It is natural to question whether the results change if we consider turnover shares in the spot or derivatives market only. Thus, column (7) adopts the currency share in contract trading as the dependent variable, which is a dominant part of FX turnover. All results are in line with the main findings established in Table 3.

In short, our main findings point to strong network effects in currency turnover, and the important role of trade share, financial depth and inflation performance in determining currency shares. The findings also appear robust against variations in variable choice, estimation method and sample specification.

5. Implications for the Renminbi

In this section, we perform counterfactual analysis for the renminbi. Our preferred empirical model is

[14] As pointed out by Tsuyuguchi and Wooldridge (2008), one should distinguish foreign exchange controls, which are regulations governing the buying and selling of the local currency, from capital controls, which regulate cross-border transactions in financial assets. They found that FX controls impede the participation of non-residents in FX markets and discourage derivatives transactions.

shown in column (6) of Table 3, upon which the rest of our analysis is based. Letting the data speak, the model keeps only the variables of interest that are statistically significant. In our view, this allows us to focus on the interactions between network effects and the key economic and financial forces driving the rise of the renminbi. We conduct alternative quantitative exercises in Appendix C, based on the model in column (5) with additional control variables, and find that the main findings are robust against this variation.

There are two types of implications that our empirical model can draw: One relates to the model-implied steady state equilibrium level(s) of the FX turnover given the fundamental conditions; the other relates to one-period-ahead model predictions of FX turnover given exogenous factors and current turnover levels. The first exercise is intended to capture potential structural change of the underlying regime as the fundamentals evolve. The second exercise is to illustrate the potential trajectory of the renminbi's role in FX markets, which integrates both adjustment along the dynamic path and shifts of the path.

We start with comparative static analysis of FX turnover in steady state equilibrium as fundamental determinants change. Suppose that the renminbi is currently in or close to the low-trade steady state equilibrium and there are no exogenous shocks. Figure 11 exhibits the steady state FX turnover share of the renminbi against the trade share of China in the world. The solid black line allows China's trade share to increase but holds all other factors constant at China's current level. Initially, the steady state FX turnover share increases only gradually as China increases its share of world trade. When China's trade share reaches around 17%, an abrupt change occurs such that the steady state FX turnover share of the renminbi jumps to a level higher than 80% and stays high as the Chinese trade share increases further. As discussed in Section 2, the mechanism behind this critical transition is that the inertia generated by network effects to remain at the low-trade steady state equilibrium is overcome only when the driving forces become favourable enough. The transition shifts the trading system to a regime of a unique high-trade steady state equilibrium.

Our empirical results demonstrate the importance of financial depth to currency internationalisation. As shown in Table 5, among the explanatory variables, the size of China's financial markets, especially that of the bond market, is a major constraint to the international use of the renminbi. For example, the bond market depth in China is lower than in many advanced (e.g., the US and Japan) and emerging (e.g., Korea and Malaysia) economies.

The dark and light red lines in Figure 11 repeat the exercise of the solid black line but with the depth of China's bond market and both bond and equity markets raised to levels comparable to those of Korea, respectively. The critical transition would occur much earlier, were China's bond market to achieve Korea's depth. Increasing the equity market depth to Korea's level would reduce the trade share required at the critical transition in a similar fashion, but to a less extent. The blue lines consider the financial depth of the US for China. The renminbi would have already been close to the critical transition if financial markets in China were as developed as in the US, given that the critical trade share is in the neighbourhood of China's actual trade share, which was 11% in 2013. However, China is now already the largest trading nation, and there may be limited room for its trade share to further expand. In contrast, financial markets in China are still in a very early stage of development. The experiment suggests that domestic financial development in China needs to play a greater role in the internationalisation of the renminbi. And this lesson is particularly relevant in light of the empirical regularity that currency trading becomes less connected to the real economy and more financialised as income increases.

We now turn to consider the dynamics of FX turnover. Table 6 presents predicted FX turnover shares in 2013 using our preferred empirical model and the 2010 data, along with the implied steady state FX turnover shares for different currencies given their underlying factors in 2013. Despite some small disparities, the one-period-ahead predictions and the steady state projections are generally close to each other. Holding the exogenous variables unchanged, the iteration of one-period-ahead prediction will stabilize at the implied steady state level in the long run. In addition, Table 6 also shows that the predicted current FX turnover share is largely close to the actual share across currencies, which suggests that our preferred empirical model fits the data well.

Figure 12 depicts the dynamics of FX turnover share as fundamental factors change over time. We assume that China's trade share continues to increase linearly at its average past growth rate from its current level into the future, holding other variables at their current level. The solid line draws the dynamics of the FX turnover share against the trade share. The adjustment process is smooth given the nature of our backward-looking model. The FX turnover share increases at a slow pace in response to trade growth when the trade share is low, but it gains momentum and accelerates as the trade share grows further until it converges to the high steady state level. The dashed line additionally allows China's bond market to deepen at its past average rate, while the dotted line keeps the current growth trend for both the bond and equity markets. This exercise shows that financial deepening, especially in bond markets, will likely put currency internationalisation onto a shorter and faster converging path.

Figure 13 displays the steady state equilibrium level and the dynamics of renminbi turnover, when China's trade share increases while holding other variables constant at their current level. The former presents structural changes without a time dimension, while the latter is a manifestation of both adjustment along, and shifts in, the dynamic path over time. The point at which the dynamic evolution begins to accelerate coincides at the critical point. The regime may shift to the one with a single steady state equilibrium, but there could be a substantial time lag for the converging process to complete. This is consistent with the US dollar taking over the pound sterling, which some economic historians argue took decades (e.g., Eichengreen and Flandreau, 2009; Schenk, 2010). Sterling remained an important international currency even after the UK lost its position as an economic superpower early in the 20th century. In other words, even if the renminbi's critical transition point is reached, we should not expect it to replace the incumbent leading currency all of a sudden.

The purpose of these quantitative experiments is not to establish precise forecasts for renminbi turnover share in the future, but rather to illustrate how the rise and fall of currencies are driven by underlying fundamentals and network effects. The point we would like to highlight is that, due to network effects, the process of renminbi internationalisation would not be a linear one even if fundamental factors change linearly.

6. Conclusion

In this paper, we sketch a simple discrete choice model of currency trading in FX markets that incorporates network effects in the use of a dominant vehicle currency. We show how multiple steady state equilibria may emerge in this setting and how critical transitions may occur as economic fundamentals change. Using the data from the BIS Triennial Central Bank Survey, we estimate a structural relation implied by the model and document the evidence of substantial network effects in FX markets. We also find that the depth of a country's financial markets, especially fixed income markets, is a key determinant of FX turnover of its currency, along with the trade share and inflation performance of the issuing country.

In order to understand the potential of the renminbi as an international currency, we conduct counterfactual analysis based on the preferred empirical model. Our findings indicate that internationalisation of the renminbi is not likely to be a linear process, but rather may entail a period of slow adjustment until arriving at the critical point. Financial deepening in China will not only generate a level effect that expands the scope of renminbi trade but also induce a structural effect that shifts the transition path.

It is important, however, to note that our model does not address the possibility of a gradual weakening of the network effects in global FX markets due to, for example, the advancement of trading technologies that may reduce the benefits of a vehicle currency in FX trading. Under these circumstances, the co-existence of a few equally dominant major currencies in the global monetary system can be envisaged.

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Table 1. Geographical Distribution of Global FX Turnover, 1995-2013

Country	1995		1998		2001		2004		2007		2010		2013	
	$ bn	%	$ bn	%	$ bn	%	$ bn	%	$ bn	%	$ bn	%	$ bn	%
United Kingdom	234	29.0	685	32.6	542	31.8	835	32.0	1,483	34.6	1,854	36.8	2,726	40.9
United States	166	20.0	383	18.3	273	16.0	499	19.1	745	17.4	904	17.9	1,263	18.9
Singapore	53	7.0	145	6.9	104	6.1	134	5.1	242	5.6	266	5.3	383	5.7
Japan	68	14.0	146	7.0	153	9.0	207	8.0	250	5.8	312	6.2	374	5.6
Hong Kong SAR	40	5.0	80	3.8	68	4.0	106	4.1	181	4.2	238	4.7	275	4.1
Switzerland	51	6.0	92	4.4	76	4.5	85	3.3	254	5.9	249	4.9	216	3.2
Australia	21	3.0	48	2.3	54	3.2	107	4.1	176	4.1	192	3.8	182	2.7
China	-	-	-	-	-	-	1	0.0	9	0.2	20	0.4	44	0.7
Others	183	16.0	520	24.8	435	25.5	634	24.3	941	22.0	1,008	20.0	1,208	18.1
Total	818	100.0	2,099	100.0	1,705	100.0	2,608	100.0	4,281	100.0	5,043	100.0	6,671	100.0

Notes: Turnover volume and share are based on daily average during April in year of survey, which is adjusted for local inter-dealer double-counting (i.e., net-gross basis).

Table 2. Currency Distribution of FX Turnover, 1989-2013

Currency	1989	1992	1995	1998	2001	2004	2007	2010	2013
USD	90.0	82.0	83.0	86.8	89.9	88.0	85.6	84.9	87.0
EUR					37.9	37.4	37.0	39.1	33.4
JPY	27.0	23.0	24.0	21.7	23.5	20.8	17.2	19.0	23.0
GBP	15.0	14.0	10.0	11.0	13.0	16.5	14.9	12.9	11.8
AUD	2.0	2.0	3.0	3.0	4.3	6.0	6.6	7.6	8.6
CHF	10.0	9.0	7.0	7.1	6.0	6.0	6.8	6.3	5.2
CAD	1.0	3.0	3.0	3.5	4.5	4.2	4.3	5.3	4.6
MXN				0.5	0.8	1.1	1.3	1.3	2.5
CNY				0.0	0.0	0.1	0.5	0.9	2.2
NZD				0.2	0.6	1.1	1.9	1.6	2.0
KRW				0.2	0.8	1.1	1.2	1.5	1.2
Others	55.0	67.0	70.0	66.0	18.7	17.6	22.7	19.8	18.4
Total	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0

Notes: (i) FX turnover share is based on daily average during April in year of survey, which is adjusted for local and cross-border inter-dealer double-counting (i.e., net-net basis). (ii) Because two currencies are involved in each transaction, the sum of the percentage shares of individual currencies totals 200%.

Table 3. GMM Estimation of Currency Turnover Model

	Dependent variable: logit (FX turnover share)					
	(1)	(2)	(3)	(4)	(5)	(6)
Lagged FX turnover share	5.923**	5.085***	5.081***	5.393***	4.739***	4.746***
	(2.641)	(1.793)	(1.888)	(1.686)	(1.608)	(1.589)
Trade share	31.274**	18.078*	16.082*	16.526*	19.996**	20.306**
	(13.486)	(9.544)	(8.390)	(8.892)	(9.041)	(9.373)
Gross capital flow	-0.484	-0.235	-0.210	-0.202		
	(0.514)	(0.303)	(0.326)	(0.285)		
Size of stock market		0.709***	0.686***	0.589***	0.509**	0.523***
		(0.244)	(0.228)	(0.224)	(0.197)	(0.191)
Size of bond market		1.055**	1.176***	0.839*	0.877**	0.915**
		(0.418)	(0.388)	(0.464)	(0.405)	(0.379)
Stock market turnover		0.102	0.035	0.113	0.137	
		(0.189)	(0.174)	(0.232)	(0.215)	
Exchange rate volatility			-3.778	2.500	0.155	
			(5.106)	(6.646)	(5.870)	
Depreciation			0.179	-0.285	-0.257	
			(0.570)	(0.377)	(0.296)	
Inflation				-10.504**	-8.253*	-6.981*
				(4.767)	(4.277)	(4.153)
Constant	-5.869***	-6.486***	-6.479***	-5.894***	-6.035***	-6.047***
	(0.311)	(0.400)	(0.600)	(0.551)	(0.469)	(0.408)
Number of groups	52	44	43	43	45	46
Number of obs.	222	191	190	190	192	193
m1	0.43	0.85	0.62	0.30	0.49	0.23
m2	1.89	0.61	1.00	0.04	0.43	1.57
Hansen	42.53	35.25	34.03	37.54	39.31	37.44

Notes: (i) All models are estimated using the system GMM estimator for dynamic panel data. Lagged FX turnover share, trade share, and gross capital flow, if included, are treated as predetermined or endogenous, while all other regressors serve as standard instruments. (ii) Hansen is the Hansen test of over-identifying restrictions. M1 and m2 are tests for first- and second-order serial correlation in the first-differenced residuals. Asymptotically robust standard errors are reported in parenthesis. ***p<0.01, **p<0.05, *p<0.1.

Table 4. Robustness of Main Estimation Results

	Dependent variable: logit (FX turnover share)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Sample	Combined 1989-2013	Combined 1989-2013	Combined 1989-2013	Combined 1989-2013	Combined 2004-2013	Public 1989-2013	Contract 1989-2013
Method	System GMM	System GMM	Random Effects	Pooled OLS	System GMM	System GMM	System GMM
Lagged FX turnover share	4.696***	4.128***	4.385***	4.699***	6.434***	5.497***	5.197***
	(1.599)	(1.091)	(1.437)	(0.761)	(1.899)	(1.773)	(1.596)
Trade share	19.769**	20.813***	36.142***	23.744***	13.150*	14.481	19.899***
	(9.066)	(6.750)	(8.806)	(4.396)	(7.077)	(9.690)	(7.096)
Financial openness	-1.446	0.311**					
	(1.016)	(0.170)					
Size of stock market	0.584***	0.485**	0.4167***	0.562***	0.562***	0.594***	0.577***
	(0.210)	(0.219)	(0.092)	(0.118)	(0.205)	(0.194)	(0.195)
Size of bond market	0.842**	0.722*	1.023***	0.831***	0.835**	0.953**	0.876**
	(0.399)	(0.422)	(0.276)	(0.210)	(0.406)	(0.450)	(0.371)
Stock market turnover	0.124	0.238					
	(0.216)	(0.167)					
Exchange rate volatility	0.176	0.401					
	(6.010)	(7.405)					
Depreciation	-0.291	-0.480					
	(0.300)	(0.321)					
Inflation	-8.955**	-3.216	-5.073*	-7.126**	-7.516*	-7.261*	-4.862
	(4.565)	(3.742)	(2.841)	(3.081)	(4.563)	(3.841)	(3.826)
Constant	-5.977***	-6.562***	-6.767***	-6.088***	-6.015***	-6.081***	-6.218***
	(0.473)	(0.439)	(0.419)	(0.301)	(0.520)	(0.453)	(0.430)
Number of groups	45	44	46		34	45	46
Number of obs.	192	190	193	193	126	161	177
m1	0.40	1.33			0.59	0.50	0.51
m2	0.35	0.19			1.09	2.01	1.83
Hansen	40.09	39.09			32.38	36.91	38.11
R-Squared			0.708	0.719			

Notes: (i) The *de facto* measure (ratio of gross foreign assets to GDP) for financial openness is used in column (1), and the *de jure* measure (Chinn-Ito index) is used in column (2). (ii) Since the Hausman test fails to reject the null hypothesis of random effects, column (3) goes for the random effect model. R-squared overall is reported. (iii) Column (6) uses the subsample that includes only the publically variable survey data on currency distribution of FX turnover. (iii) See Table 3 for other notes on GMM estimation. (iv) Asymptotically robust standard errors are reported in parenthesis. ***p<0.01, **p<0.05, *p<0.1.

Table 5. Current Status of FX Turnover and Explanatory Variables by Currency

	USD	JPY	CNY	KRW	MYR
Dependent Variable					
FX turnover share (%)	87.046	23.038	2.237	1.201	0.398
Explanatory variable					
Trade share	0.102	0.041	0.110	0.029	0.012
Gross capital flow	0.092	0.118	0.112	0.085	0.141
Chinn-Ito index	2.439	2.439	-1.169	0.942	-1.169
Ratio of gross foreign assets to GDP	0.032	0.020	0.011	0.014	0.023
Size of financial institutions	1.877	1.777	1.215	0.984	1.064
Size of stock market	1.102	0.686	0.587	0.962	1.441
Size of bond market	1.796	2.444	0.510	1.208	1.052
Stock market turnover	1.862	1.029	1.784	1.895	0.311
Exchange rate volatility	0.002	0.009	0.003	0.005	0.006
Depreciation	0.004	-0.098	0.105	0.060	0.026
Inflation	0.017	-0.009	0.018	0.010	0.007

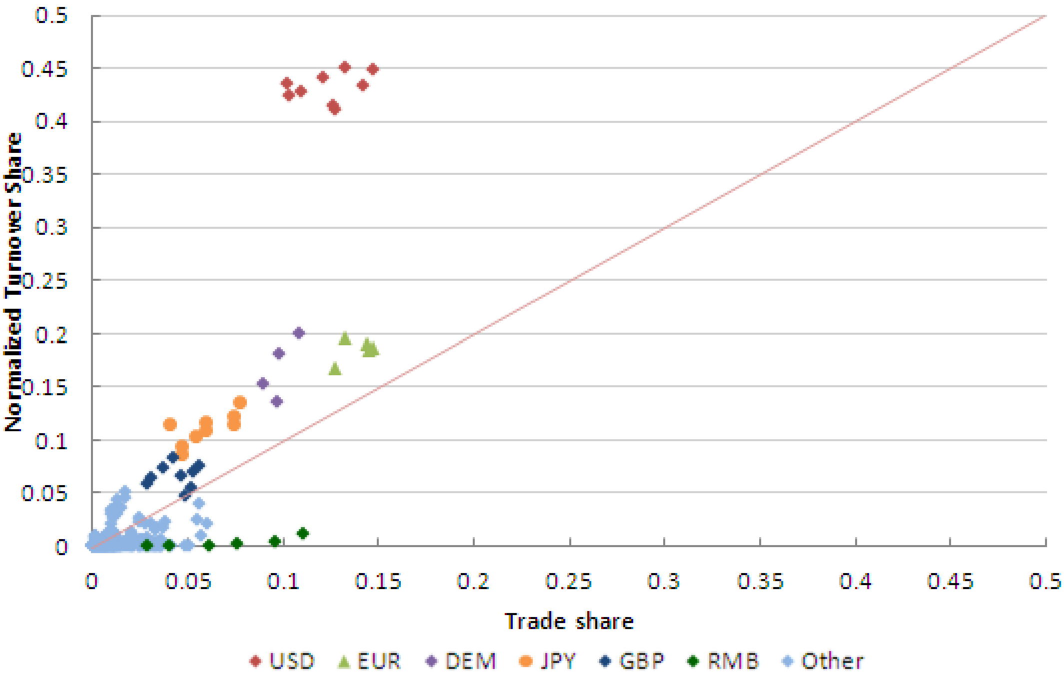
Data Source: See Table B.1.

Table 6. Model Predictions for FX Turnover by Currency

	USD	JPY	CNY	KRW	MYR
Actual current FX turnover share	87.046	23.038	2.237	1.201	0.398
Predicted current FX turnover share	84.271	11.420	2.687	1.303	1.007
Predicted steady state FX turnover share	83.194	6.716	2.960	1.289	1.045

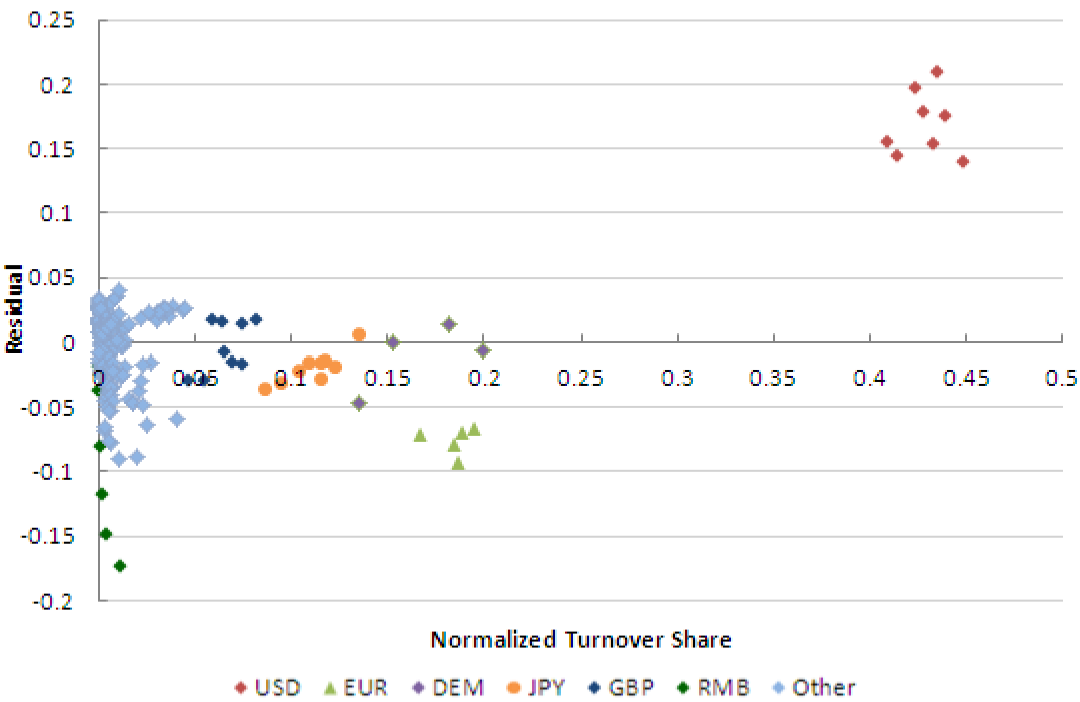
Data Source: Authors' estimates.

Figure 1. FX Turnover Share of Currency and Global Trade Share of Issuing Country



Notes: (i) FX turnover share is normalized so that it sums up to 1 over all currencies in each period. (ii) Trade share is adjusted for intra-euro area trade.
Data Source: BIS, WTO.

Figure 2. OLS Residuals of Linear Model for FX Turnover by Currency



Notes: (i) OLS residuals are obtained by regressing the normalized FX turnover share of currencies on explanatory variables that include global trade share of the currency issuing country, size of its stock market, size of its bond market, and inflation rate, without a constant term. (ii) See Table B.1. for details of the variables and data sources.

Figure 3. Average Trading Choices with Unique Steady State Equilibrium

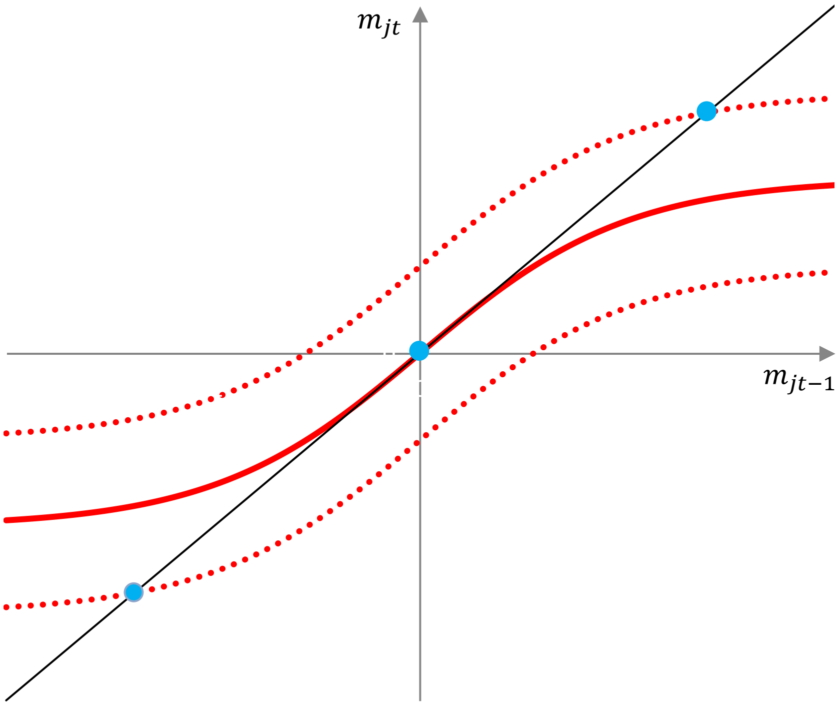


Figure 4. Average Trading Choices with Multiple Steady State Equilibria

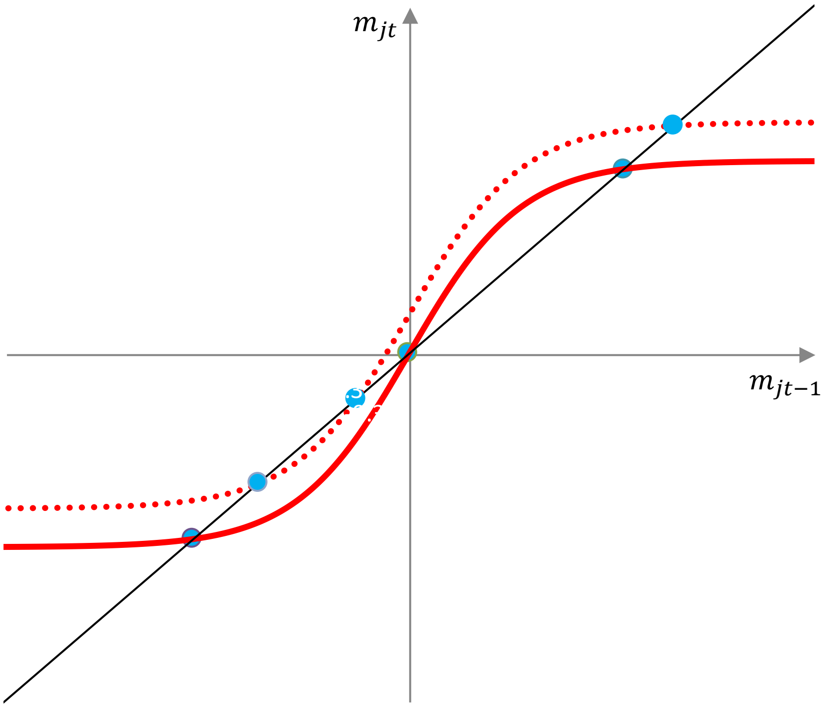


Figure 5. Multiple Steady State Equilibria and Critical Transitions

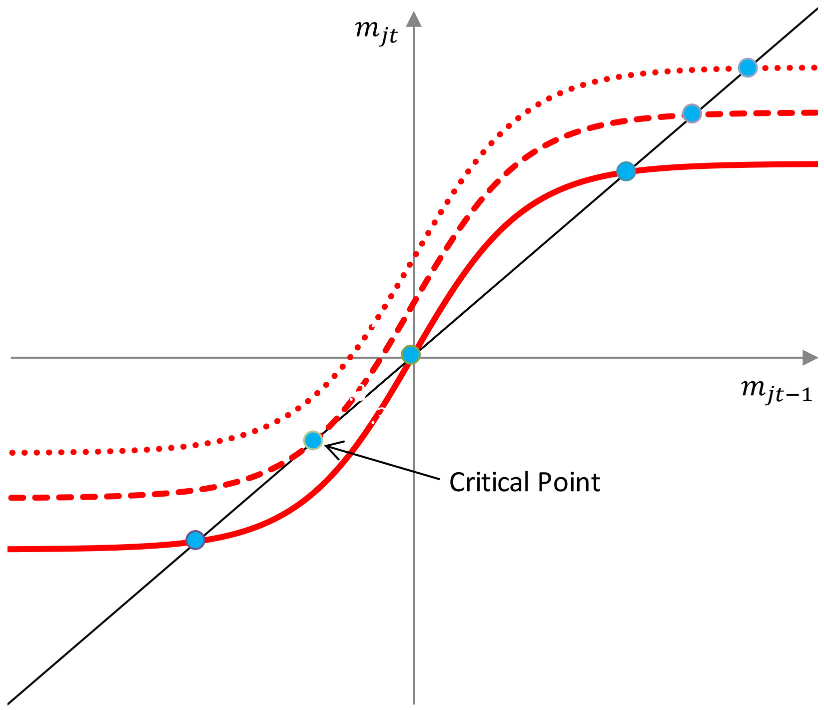


Figure 6. Converging Process toward the Steady State Equilibrium

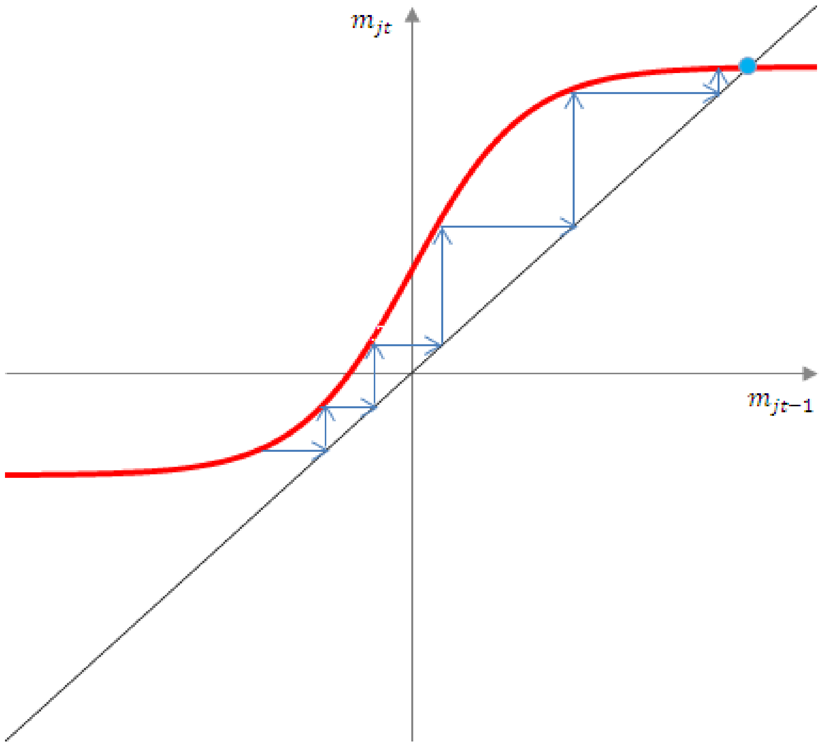
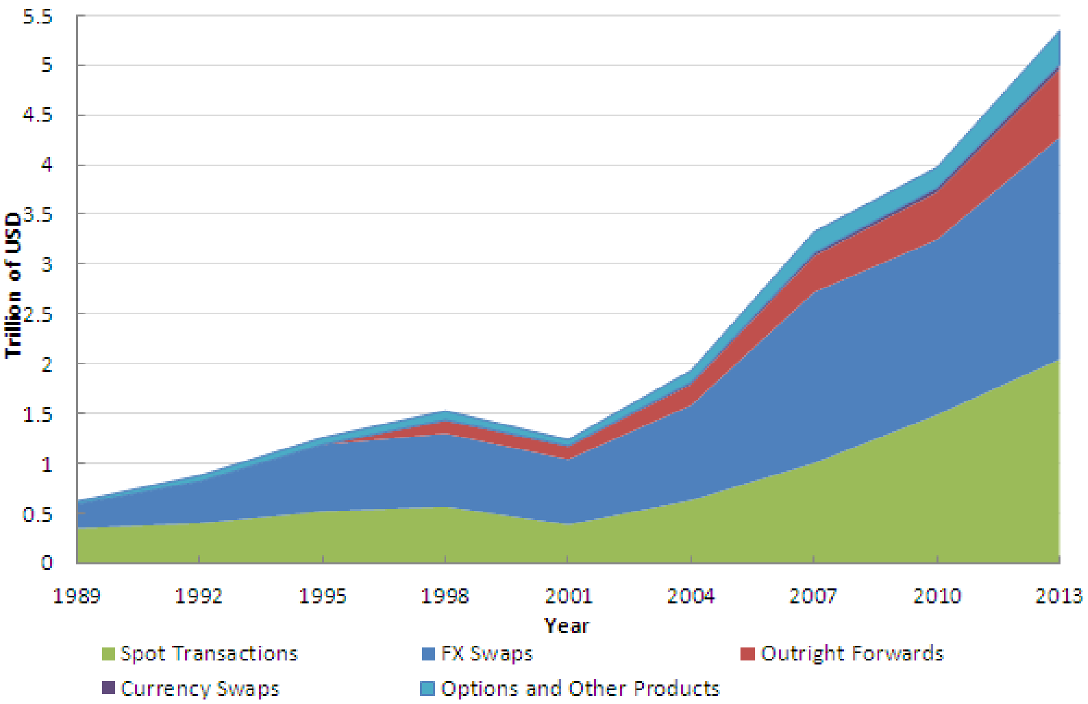
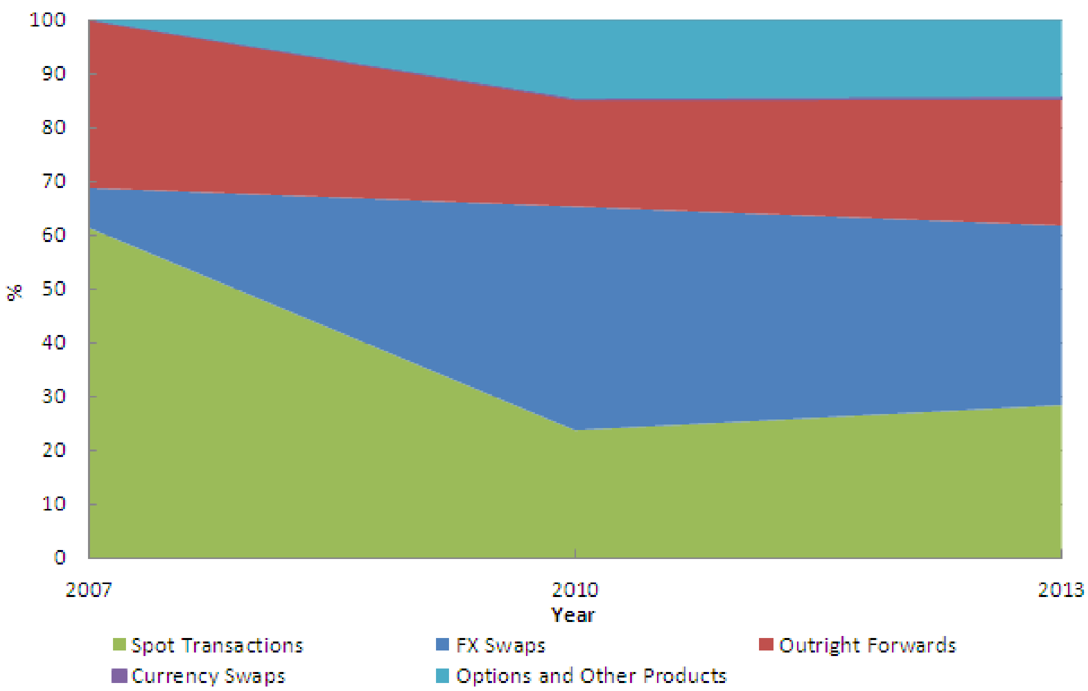


Figure 7. Global FX Turnover by Instrument, 1989-2013



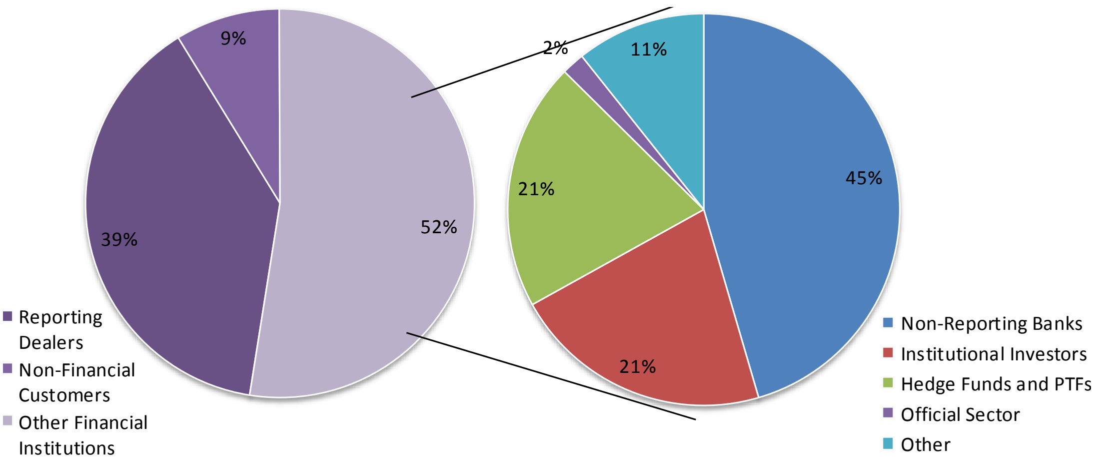
Notes: FX turnover is daily average during April in the year of survey, adjusted for local and cross-border inter-dealer double-counting, i.e., net-net basis.
Data Source: BIS.

Figure 8. Renminbi Turnover by Instrument, 2007-2013



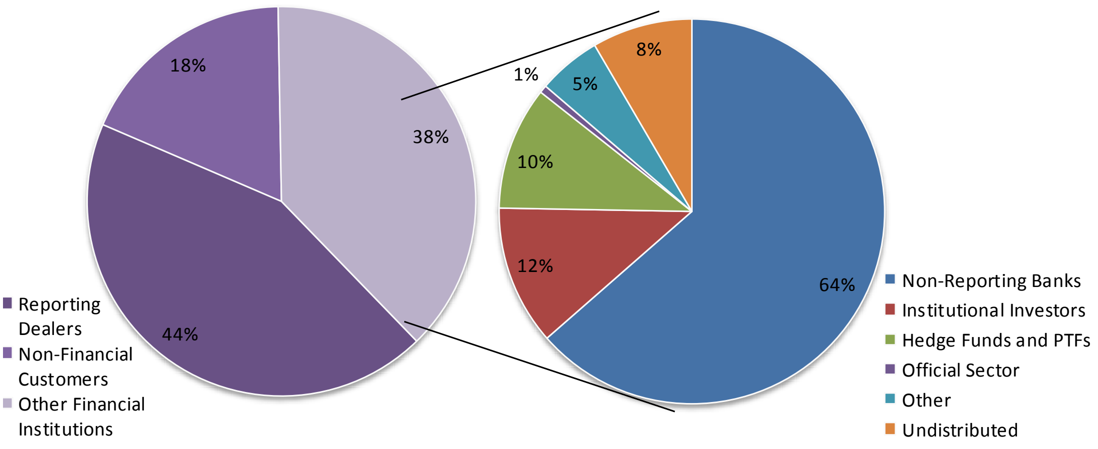
Notes: Instrument distribution of renminbi turnover is calculated from daily average data for April in the year of survey, which is adjusted for local and cross-border inter-dealer double-counting (i.e., net-net basis).
Data Source: BIS.

Figure 9. Global FX Turnover by Counterparty in 2013



Notes: Turnover share by counterparty is calculated from daily average data for April 2013, which is adjusted for local and cross-border inter-dealer double-counting (i.e., net-net basis).
Data Source: BIS.

Figure 10. FX Turnover in China by Counterparty in 2013



Notes: Turnover share by counterparty is calculated from daily average data for April 2013, which is adjusted for local and cross-border inter-dealer double-counting (i.e., net-net basis).
Data Source: BIS.

Figure 11. Steady State Equilibrium FX Turnover Share of the Renminbi under Different Conditions

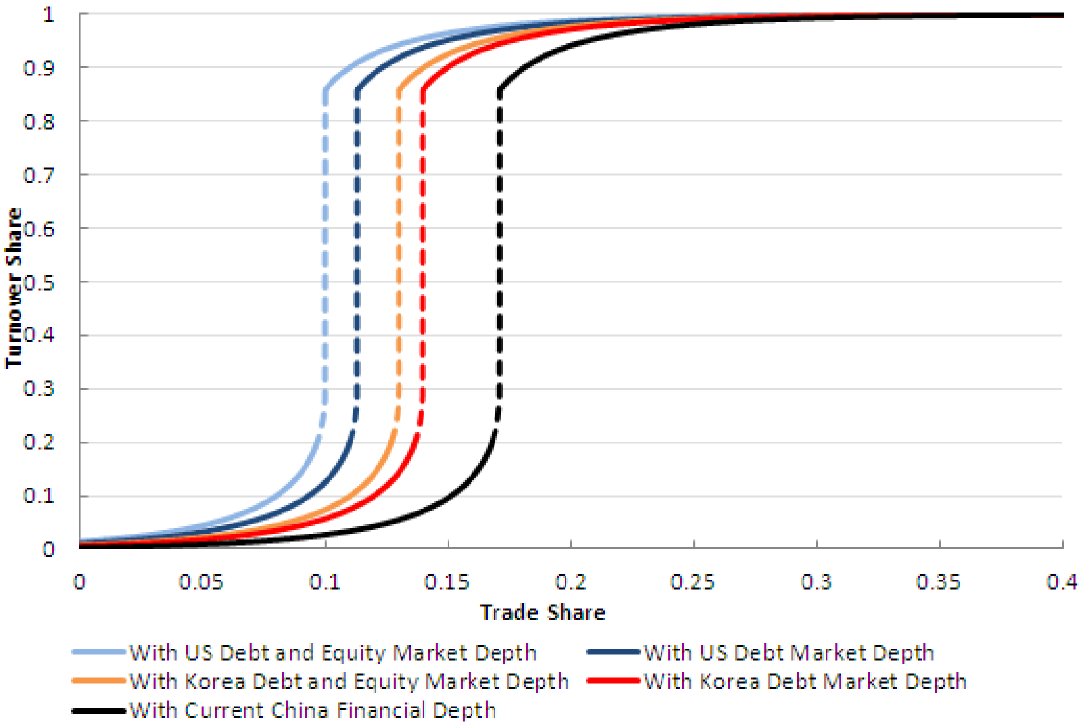


Figure 12. Dynamic FX Turnover Share of the Renminbi under Different Conditions

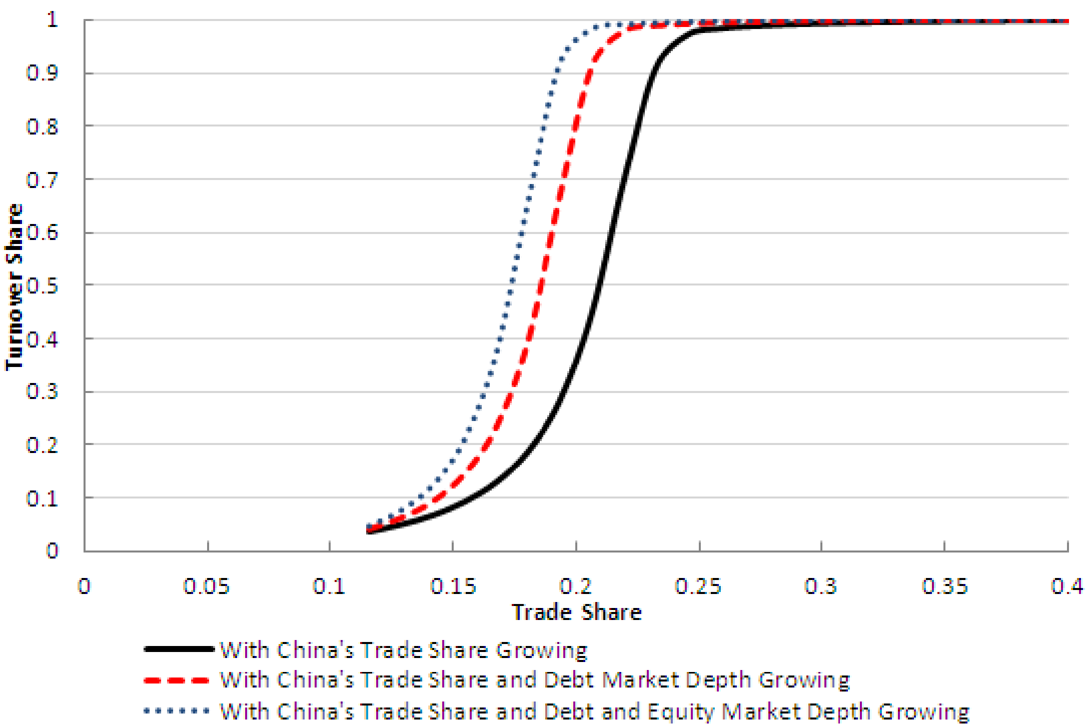
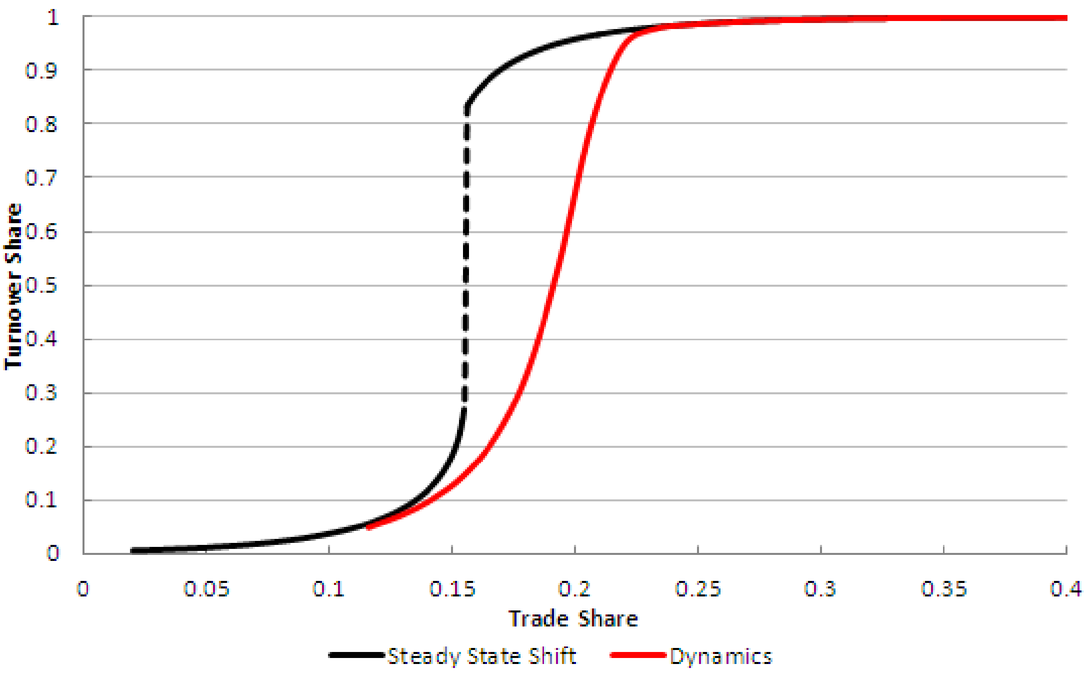


Figure 13. Steady State Equilibrium Transition and Dynamic Path of FX Turnover Share of the Renminbi as China's Trade Share Grows



Appendix A. Supplementary Results of the FX Turnover Model

This appendix contains some additional results of the FX turnover model presented in Section 2. To begin with, we observe that the payoff function can be made more general, such as

$$\Pi_{jt}^{i}\left(c_{jt}^{i}, c_{jt}^{-i}\right) = u_{jt}\left(c_{jt}^{i}\right) + v_{jt}\left[c_{jt}^{i}, E\left(c_{jt}^{-i}\right)\right] + \xi\left(c_{jt}^{i}\right), \tag{A.1}$$

where $E(c_{jt}^{-i})$ is the expected profile of the choices of all traders in the population I_j other than i. The first component $u_{jt}\left(c_{jt}^{i}\right)$ is only a function of the trader's own choice. The second component $v_{jt}\left[c_{jt}^{i}, E(c_{jt}^{-i})\right]$ takes into account the interactions in the market. The last term $\xi(c_{jt}^{i})$ is again an independently and identically distributed random component.

Our use of payoff function (1) in Section 2 is to obtain the analytical solution. When $\rho > 0$, payoff function (1) exhibits a strategic complementarity, which is necessary for the emergence of multiple equilibria (Cooper and John, 1988). Under the general specification (A.1), the necessary condition is that $\frac{\partial^2 v_{jt}}{\partial c_{jt}^{i} \partial E(c_{jt}^{-i})} > 0$.

In the original setting (1)-(3), the *ex ante* probabilities for $c_{jt}^{i} = 1$ and that $c_{jt}^{i} = -1$ are given as, respectively,

$$\Pr\left(c_{jt}^{i} = 1\right) = \frac{\exp\left[\theta\left(\phi_{jt} + \rho m_{jt-1}\right)\right]}{\exp\left[\theta\left(\phi_{jt} + \rho m_{jt-1}\right)\right] + \exp\left[-\theta\left(\phi_{jt} + \rho m_{jt-1}\right)\right]} \tag{A.2}$$

$$\Pr\left(c_{jt}^{i} = -1\right) = \frac{\exp\left[-\theta\left(\phi_{jt} + \rho m_{jt-1}\right)\right]}{\exp\left[\theta\left(\phi_{jt} + \rho m_{jt-1}\right)\right] + \exp\left[-\theta\left(\phi_{jt} + \rho m_{jt-1}\right)\right]} \tag{A.3}$$

In these expressions, θ parameterizes the extent to which the deterministic payoff component determines actual choice. As $\theta \to \infty$, the effect of $\xi(c_{jt}^{i})$ on the realized choice will vanish, whereas as $\theta \to 0$, the probabilities for $c_{jt}^{i} = 1$ and $c_{jt}^{i} = -1$ will converge to 0.5, regardless of the values of other terms. As discussed, it is also clear that the probability for i to trade is larger when more traders are expected to trade, i.e. when m_{jt-1} is larger, and the probability not to trade is larger when more traders choose not to trade, i.e. when m_{jt-1} is smaller. In the absence of network effects, $\rho = 0$, the trading decisions completely rely on the relative private payoffs from trading.

To determine the average choice, notice that $\Pr\left(c_{jt}^{i} = 1\right)$ also represents the fraction of traders in the population I_j choosing to trade currency j at time t. Similarly, $\Pr\left(c_{jt}^{i} = -1\right)$ represents the percentage of not trading. Thus,

$$m_{jt} = 1 \cdot \frac{\exp[\theta(\phi_{jt} + \rho m_{jt-1})]}{\exp[\theta(\phi_{jt} + \rho m_{jt-1})] + \exp[-\theta(\phi_{jt} + \rho m_{jt-1})]}$$
$$+(-1) \cdot \frac{\exp[-\theta(\phi_{jt} + \rho m_{jt-1})]}{\exp[\theta(\phi_{jt} + \rho m_{jt-1})] + \exp[-\theta(\phi_{jt} + \rho m_{jt-1})]} \quad \text{(A.4)}$$

The right hand side of (A.4) is a hyperbolic function. Dynamic equation (4) then follows.

The existence of steady state equilibrium is guaranteed by the facts that the $tanh$ function is a continuous mapping and that the support of the choice profile is $\{-1,1\}^{I_j}$. Brouwer's fixed point theorem implies that there must exist a fixed point with respect to m_j such that (6) hold. In other words, holding exogenous factors constant, there exists at least one steady state equilibrium in which the average choice is defined by (6).

As discussed in Section 2, network effects may give rise to multiple steady state equilibria, i.e., distinct average choices may be each compatible with individually optimal decisions. The following results summarise the analysis shown in Figures (3)-(5):

(1) When $\theta\rho < 1$, there is only one steady state equilibrium. In equilibrium, $m_j^* = 0$ if $\phi_j = 0$, $m_j^* > 0$ if $\phi_j > 0$, and $m_j^* < 0$ if $\phi_j < 0$.

(2) When $\theta\rho > 1$ and $\phi_j = 0$, there exist three steady state equilibria. One equilibrium has $m_j^* = 0$, one has $m_j^* > 0$, and one has $m_j^* < 0$. The last two are symmetric.

(3) When $\theta\rho > 1$ and $\phi_j \neq 0$, there exists a threshold Φ, which depends on the value of $\theta\rho$, such that: (a) for $|\theta\phi_j| < \Phi$, there exist three steady state equilibria, in one of which m_j^* has the same sign as ϕ_j, and in the others m_j^* possesses the opposite sign; (b) for $|\theta\phi_j| > \Phi$|, there exists a unique steady state equilibrium, in which m_j^* has the same sign as ϕ_j.

Therefore, a tipping phenomenon occurs at the threshold when $|\theta\phi_j| = \Phi$. In the limit case, when the intrinsic value is infinite $\phi_j \to \infty$, almost all traders will execute the trading opportunities $m_j^* \to 1$, while $\phi_j \to -\infty$, $m_j^* \to -1$. On the other hand, when the external effects is infinitely strong, the economy coverage to $m_j^* \to -1$ or 1 with $\phi_j \neq 0$ and $m_j^* \to -1, 0,$ or 1 with $\phi_j = 0$.

Local stability of steady state equilibrium is governed by the derivative of m_{jt} with respect to m_{jt-1} in the neighbourhood of the equilibrium, as implied by (4). Following Brock and Durlauf (2001), the analysis obtains:

(1) If equation (6) has a unique root, that root is locally stable.

(2) *If equation (6) has three roots, the average choices in the high-trade and low-trade steady state equilibria are locally stable, while the average choice in the mixed steady state equilibrium is locally unstable.*

Finally, for empirical implementation, the change of variables by substituting (5) into (4) yields

$$y_{jt} = \frac{\exp\{2\theta[\phi_{jt} + \rho(2y_{jt-1} - 1)]\}}{\exp\{2\theta[\phi_{jt} + \rho(2y_{jt-1} - 1)]\} + 1} \tag{A.5}$$

Rearranging terms and taking the natural logarithm give equation (7). As discussed in Section 2, the empirical model (9) is then fully specified.

Appendix B. Data Source and Descriptive Statistics

Table B.1 Measurement and Data Source

Variable	Description	Unit	Source
FX turnover share (%)	Turnover share of a currency in the global foreign exchange (FX) market	Percentage Point	BIS Triennial Survey
Trade share	Ratio of the cross-border trade (sum of export and import values in merchandise trade) of the currency issuing country to the total trade value of the whole world	Percentage	WTO, OECD
	Trade within the euro area are excluded from the cross-border trade of the euro area economy and the total trade of the world		
Gross capital flow	Ratio of the gross capital flow of the issuing country to its GDP, with the gross capital flow being the sum of the absolute value of capital inflow and outflow, which include direct investment, portfolio investment, and other investment	Percentage	IMF
Financial openness	The *de jure* measure: the Chinn-Ito index, a measure of the currency issuing country's degree of capital account openness based on the binary dummy variables that codify the tabulation of restrictions on cross-border financial transactions	-	Chinn and Ito (2006), updated
	The *de facto* measure: ratio of international assets and liabilities of the issuing country to its GDP	Percentage/100	Lane and Milesi-Ferretti (2007), updated
Size of financial institutions	The currency issuing country's domestic credit to the private sector as a percentage of GDP	Percentage	World Bank
Size of stock market	The currency issuing country's stock market capitalization as a percentage of GDP	Percentage	World Bank
Size of bond market	The currency issuing country's total size of public and private debt securities as a percentage of GDP	Percentage	World Bank
Stock market turnover	Ratio of the value of total shares traded to market capitalization in the currency issuing country	Percentage	World Bank
Exchange rate volatility	Standard deviation of daily change of the exchange rate of a currency against SDR	Percentage	Bloomberg
Depreciation	Year-on-year change of the average daily exchange rate of a currency against SDR	Percentage	Bloomberg
Inflation	Inflation rate of the GDP deflator of the currency issuing country	Percentage	World Bank

Table B.2 Descriptive Statistics of Main Variables

Variable	Mean	Standard deviation	Min	Max	Number of obs.
Dependent Variable					
FX turnover share (%)	5.891	16.319	0.001	90.000	286
Independent Variable					
Trade share	0.019	0.027	0.000	0.147	463
Gross capital flow	0.451	2.082	0.004	26.631	458
Chinn-Ito index	1.173	1.493	-1.864	2.439	435
Ratio of gross foreign assets to GDP	0.059	0.225	0.002	2.402	461
Size of financial institutions	0.775	0.490	0.056	2.335	431
Size of stock market	0.651	0.653	0.000	5.244	386
Size of bond market	0.573	0.435	0.000	2.444	349
Stock market turnover	0.693	0.617	0.003	5.382	385
Exchange rate volatility	0.072	1.179	0.002	23.957	413
Depreciation	-0.042	0.189	-0.999	0.455	407
Inflation	0.332	2.284	-0.140	30.576	461
Year			1989	2013	

Appendix C. Quantitative Exercises Based on the Alternative Model

In this section, we carry out the same set of quantitative exercises in Section 5 using the empirical model reported in column (5) of Table 3. The following figures are comparable with Figures 11-13, respectively. Quantitative predictions may be somewhat different from what implied by the preferred model, but the dynamics and transitions do not change much relative to the benchmark simulations. The discussions contained Section 5 continue to follow here. We would like to add that quantitative experiments are not supposed to establish precise numbers but to convey our idea on the framework for thinking about currency internationalisation.

Figure C.1 Steady State Equilibrium FX Turnover Share of the Renminbi under Different Conditions

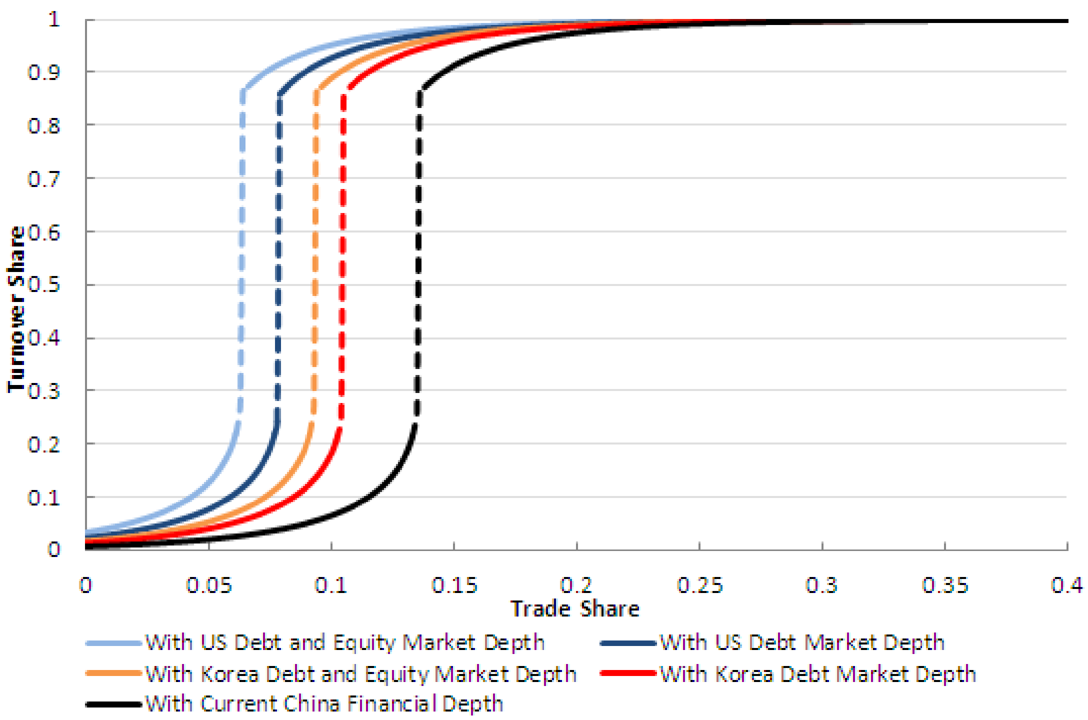


Figure C.2 Dynamic FX Turnover Share of the Renminbi under Different Conditions

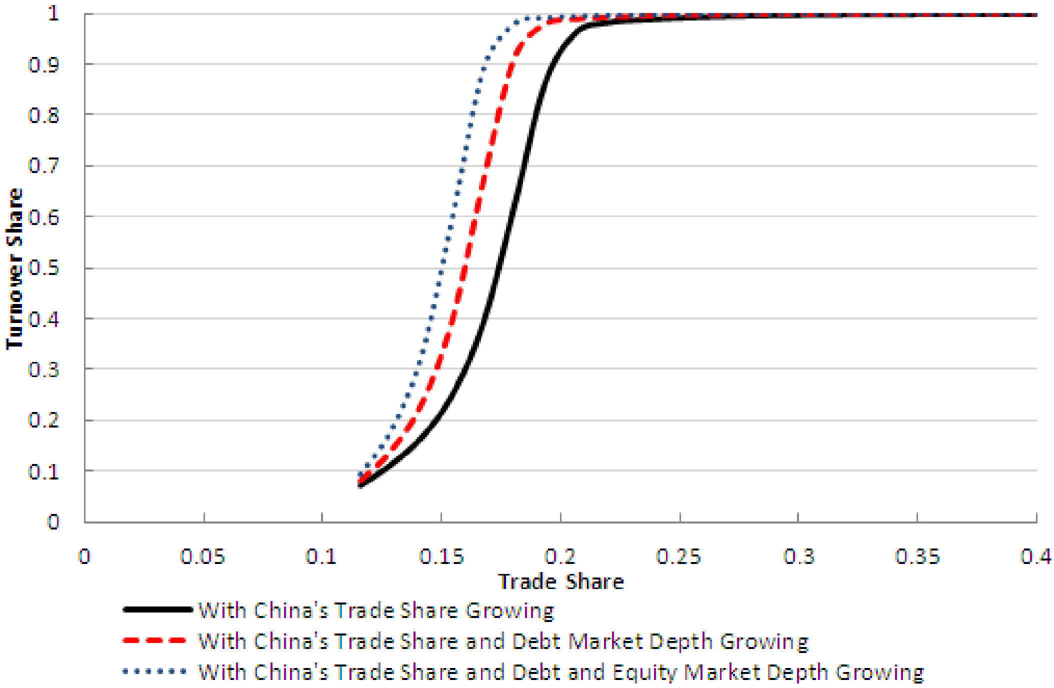


Figure C.3 Steady State Equilibrium Transition and Dynamic Path of FX Turnover Share of the Renminbi as China's Trade Share Grows