Trade Finance and International Currency: A Monetary Search Approach*

Job Market Paper

Tao Liu†

University of California, Davis

Abstract

The paper studies the determinants of currency choice in trade. Previous literature focused on economy size and openness, but that couldn't explain why RMB remains largely national while China is already leading in international trade. This paper highlights the importance of financial development for currency internationalization. First I use SWIFT dataset to empirically verify the significance of financial development. Then I build a two-country monetary search model in which trade takes time, and the lack of commitment makes exporter and importer rely on bank-intermediated finance. The agent's currency choice is related with terms of trade, monetary policy, and financial efficiency. Optimal monetary policy differs according to currency regime. Related topics such as size effect and global imbalance are also discussed.

JEL Classification: E40, E50, F33, F41
Keywords: trade finance, RMB internationalization, monetary search, global imbalance.

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†Correspondence: Department of Economics, University of California Davis, Davis, CA 95616. Email: taoliu@ucdavis.edu

1 Introduction

The international monetary system came under serious doubt after the global financial crisis in 2008. Many alternatives have been proposed to replace the exorbitant privilege of US dollar (USD), such as Special Drawing Rights (Zhou, 2009), a multi-polar system (Eichengreen, 2011), and a single world currency (Mundell, 2012). Academic research on international currency normally emphasized economy size and openness, but historical experience shows another picture. U.S. GDP surpassed Great Britain in 1870s, and U.S. share of world export surged to 22.1% in 1913, but the international role of USD was essentially zero, while Sterling still invoiced over 60% of world trade in early 1900s (Broz, 1997). The establishment of FED is believed to speed up the rise of USD, with its favorable policy towards developing financial market and providing trade credit (Eichengreen and Flandreau, 2012). Given this background, I show that a sound financial market is indispensable for currency internationalization, which could explain why Renminbi (RMB) remains largely national while China is already leading in international trade.

To that end, I first verify the importance of financial development using trade finance data from SWIFT (Society for Worldwide Interbank Financial Telecommunication). A two-country monetary search model is then built to explain this finding. Goods are assumed to be delivered one period after contract, and the lack of commitment calls for bank to provide liquidity to exporter with the fund from investor, who would later get payoff from importer. Banking sector operates at a fixed cost, and exporter receives liquidity at discount, so he would choose the currency with a higher level of profit. Consequently, a currency is never used in international trade if the issuing country doesn't have a liquid and efficient financial market.

In equilibrium, each country's welfare function consists of gains from trade as well as the seigniorage revenue. For a central bank trying to maximize social welfare, Friedman rule of zero nominal interest rate is not necessarily optimal, given the trade-off between gains from trade and seigniorage revenue. In addition, the relationship between optimal inflation level and economy size is hump-shaped: for a relatively large or small economy, the seigniorage revenue is dwarfed by gains from trade, so lower inflation is a better choice.

Moreover, this model provides an intuitive explanation for global imbalance, characterized by the persistent current account deficit of United States. In a symmetric model, if country 1 issues the only international currency, its resident holds more of country 1 currency since it's used for both domestic and international trade. In contrast, country 2 resident holds less of country 1 currency since he could use it for only international trade.

As a result, the over-consumption tendency of country 1 leads to its trade deficit. This model therefore implies that global imbalance is partially attributed to the status of USD as the dominant international currency.

For definition, a currency becomes international when used by foreigners in locations outside of the issuing country. As store of value, it could be central bank's international reserve or private agent's investment instrument. As medium of exchange, it could smooth government's foreign exchange (FX) intervention or settle international trade. As unit of account, it denominates financial transaction or becomes the anchor of other currencies. Table 1 summarized all these functions.

Table 1: The roles of international money

	Medium of exchange	Unit of account	Store of value
Private sector	Trade settlement	Asset denomination	Investment instrument
Central bank	FX intervention	Currency anchor	International reserve

Source: adapted from Cohen (1971)

This paper is focused on the international currency as medium of exchange[1], so it's necessary to define the pattern of currency use in international trade. Here I would follow the convention in international macroeconomics with the use of Producer Currency Pricing (PCP), Local Currency Pricing (LCP), and Vehicle Currency Pricing (VCP). If the international trade is settled by the home currency of exporter (importer), it's defined as PCP (LCP). Otherwise, if a third-country currency is used to settle international trade, it's defined as VCP[2].

Academic research on international currency spans economics and politics. Interested reader could refer to Bénassy-Quéré (2015) for a systematic review. For economic theories

[1]In practice, there's a lot of difference among pricing, invoicing, and settlement currency, although theoretical model usually takes them as equivalent. Pricing or invoicing currency might be considered as unit of account, while settlement currency is naturally classified as medium of exchange. Friberg and Wilander (2008) conducted a questionnaire study on the currency choice of Swedish exporter in 2006, and most firms reported to use the same currency in over 90% of their revenue. Of course, the discrepancy could be large, especially for developing countries. Reiss (2015) found that, for Brazil real, its use as invoicing currency is more than settlement currency, whereas Yu (2013) suggested that RMB was used more as settlement currency than invoicing currency.

[2]In this paper, I use settlement currency and pricing currency interchangeably.

that regarded international currency as the outcome of decentralized choice by private agent, they could be loosely classified into trade models, invoicing currency models, and search models.

Trade models mostly used N-country general equilibrium to explain the phenomenon of international vehicle currency (IVC) (Rey, 2001; Devereux and Shi, 2013). In models of this fashion, international trade is exogenously assumed to be settled by exporter's home currency, i.e., producer currency pricing (PCP). Foreign exchange transaction is undertaken by financial intermediary or trading post with an increasing-return-to-scale technology that lowers transaction cost with a large trade volume. Under the assumption of cash in advance and PCP, agent's currency choice is exogenously given. The existence of a general equilibrium with IVC is crucially dependent on economic openness. Therefore, the currency issued by a country intensively engaged in international trade would emerge as IVC. This thick market externality also makes the status of IVC a natural monopoly. The advantage of such model comes from its nature of general equilibrium: the welfare gain of using IVC could be analyzed, and discussion on optimal monetary policy is feasible. The lack of micro-foundation, however, constitutes an obvious drawback: agent's currency choice is exogenously given, so it's impossible to explain the rise and fall of different currency regimes.

Invoicing currency models endogenized currency choice by allowing exporters to set price one period before exchange rate shock is realized. For PCP, there's uncertainty in foreign demand and production cost, while local currency pricing (LCP) makes future price unpredictable. So exporters choose invoicing currency mainly to mitigate exchange rate risk. Bacchetta and Van Wincoop (2005) showed that producer's currency choice is affected by competition in foreign markets: a higher level of exporter's market share and product differentiation tends to promote PCP. Goldberg and Tille (2008, 2013) continued this approach to include vehicle currency, and the determinants of invoicing currency include exporter's motive to limit output volatility, hedge macroeconomic volatility, and reduce transaction cost. For all its success, invoicing currency model is not explicit about the underlying process of currency circulation, and its nature of partial equilibrium also limits welfare analysis.

Search theory is interested in the rise of fiat money as medium of exchange. Earlier studies suffered from the indivisibility of output and money (Matsuyama et al., 1993) or inability to reach equilibrium (Trejos and Wright, 1996). With the breakthrough in Lagos and Wright (2005), search theory is now widely applied to topics in international macroeconomics such as home bias puzzle (Geromichalos and Simonovska, 2014) and UIP puzzle

(Jung and Lee, 2015)[3]. This paper benefits from the historical experience of international currency described in Eichengreen (2011) and incorporates trade finance to the two-country search money in Zhang (2014).

This paper also follows a long tradition of explicitly modeling bank and credit since Diamond and Dybvig (1983). One difficulty in this field is the conflict between money and credit, as pointed out by Berentsen et al. (2007). There must be an absence of record keeping for money to be essential, but credit requires record keeping in case of default[4]. The inherent tension between money and credit is not present in this model thanks to the institutional setup of trade finance: importer has no incentive to default since that would deny him the ownership of goods. Credit could coexist with money and improve welfare by facilitating international trade.

The rest of this paper is organized as follows. Part 2 presents an empirical analysis of international currency with SWIFT dataset. Part 3 describes model environment and defines monetary equilibrium. Part 4 undergoes discussion on related topics such as size effect and global imbalance. Part 5 concludes.

2 An empirical analysis with SWIFT dataset

This part documents the practice of trade finance and takes advantage of SWIFT dataset to emphasize the importance of financial development for currency internationalization.

2.1 International trade finance

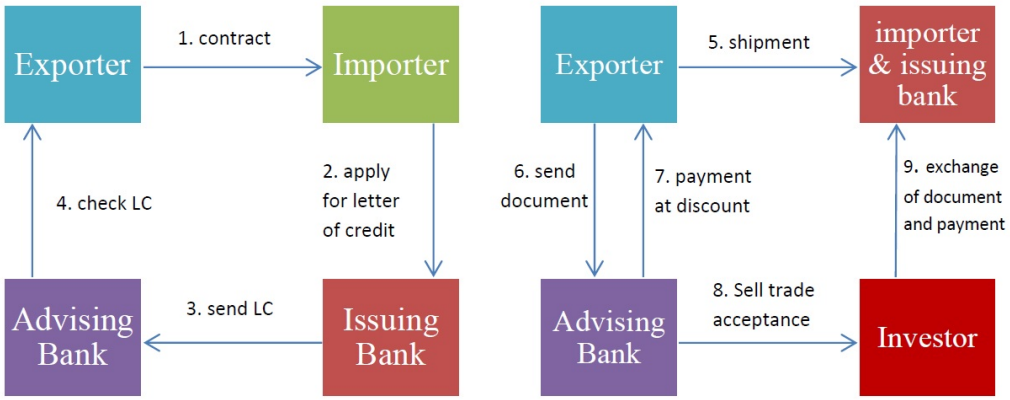
The timing of payment and delivery is always a big issue for international trade. Without mutual trust or history record, the direct trade between importer and exporter is almost impossible: importers don't know whether they could get goods after payment, and exporters are not guaranteed payment after delivery. According to the timing of payment and delivery, trade finance could be classified into *Cash-in-advance* (payment before delivery),

[3]This class of model has a large concern on asset, usually supplied in the manner of Lucas tree. The asset plays as both store of value in its claim to future output, and medium of exchange in acting as collateral to facilitate trade. My model is focused on fiat money as medium of exchange so asset pricing only has minor effect on equilibrium condition. Moreover, buyer is assumed to get goods one period after contract, so he would never give asset to seller as payment without further guarantee.

[4]This conflict is solved in Berentsen et al. (2007) by assuming banks are able to record financial transaction but not goods trade, so fiat money still circulates as medium of exchange but credit becomes feasible. Bignon et al. (2013) continued this approach to discuss the implication for currency union and financial integration. However, search model in this fashion still forces foreign consumption to be settled by foreign currency or credit, so it's improper for the discussion of international currency.

Open account (payment after delivery), and *Bank trade finance*. If importer and exporter trust each other, cash-in-advance or open account would be a better choice owing to their relatively lower transaction cost. If exporter doesn't trust importer but believe the credit of importer's bank, bank-intermediated finance could help facilitate international trade. Committee on the Global Financial System (2014) estimated that bank credit directly supports about one-third of global trade. One mainstream instrument covering half of bank trade finance is letter of credit (LC). Figure 1 illustrates its mechanism, and detailed procedures are relegated to appendix A.6[5].

Figure 1: Mechanism of LC



Source: adapted from Niepmann and Schmidt-Eisenlohr (2014)

The mismatch of timing between shipment and payment is easily solved by LC: the exporter gets timely fund once he shows shipment document and the importer is charged only after the delivery of goods. Holding LC is not attractive for banks given its average maturity of 2-3 months, but investors would be interested in this short-term asset whose payment is guaranteed by bank credit. So banks would package LC as trade acceptance and sell it to investors. In the end, banks facilitate international trade by playing the role

[5]Recently there's a rising literature on trade finance theory, such as Ahn (2015) and Schmidt-Eisenlohr (2013). Their main concern is the contract choice on trade finance, i.e. the optimal choice among cash-in-advance, bank's trade finance, and open account. Firm's choice mostly depends on default probability and the difference in financing cost. Ahn (2015) pointed out that most of Colombia import is conducted in open account, but such observation is not in conflict with my paper: in bank's trade finance, exporter's profit depends on the financial development in trade acceptance market; in open account, exporters use account receivables as collateral to get loan from bank, so their profit also depends on the financial development of banking system, although an alternative measure should be considered, such as total factoring share.

of intermediation among exporters, importers, and investors.

2.2 Empirical analysis of international currency use in trade

This section empirically verifies the significance of financial development for currency internationalization. With better data availability in recent years, cross-country analysis of trade invoicing currency becomes feasible, and the leading research includes Kamps (2006), Goldberg and Tille (2008), Ito and Chinn (2013), Gopinath (2015), and Ito and Kawai (2016). They collect data mainly from the survey of central banks, government agencies, and statistical institutes. The importance of market share, product differentiation, and financial development is generally verified. One fallacy of this approach, however, comes from the measurement inconsistency. Also, its sample size is quite limited, covering only 35 countries and regions.

SWIFT dataset provides an innovative insight on the currency use in international trade. It involves over 200 countries and territories with detailed information on trade settlement currency. As shown in Table 2, U.S. is able to use home currency in over 98% of its export and import. With the exception of Germany who is able to settle 47.51% of its export with home currency, most countries use USD as vehicle currency to finish their international trade. China made some progress in settling 23.22% of its import with home currency, but not so for export, where only 0.69% is done in RMB[6].

Table 3 provides panel analysis for the determinants of trade settlement currency, with the following regression

$$s_{ijk}^t = \beta_1 X_{ij}^t + \beta_2 (\mathrm{FD}_i^t - \mathrm{FD}_j^t) + \epsilon_{ij}^t$$

where subscript i denotes export country, j for import country, k for settlement currency, and superscript t for period. The dependent variable s_{ijk}^t is the share of trade settled in currency k. The independent variable X_{ij}^t is a vector of conventional determinants of settlement currency, including market share, inflation differential, exchange rate, distance, product differentiation, and difference in real GDP. Moreover, the independent variable also

[6]There should be some caution with the interpretation of table 2. Although letter of credit is estimated to directly support one sixth of total merchandise trade, its coverage is unbalanced across regions. Less than 10% of US export is linked with bank trade finance, whereas Asian countries heavily relies on it. This is also true for mainland China: around 30% of its import is financed by letter of credit, but that share is less than 10% for export. For comparison, data from PBOC and China's custom showed that 20.94% of China's merchandise trade was settled by RMB in November 2015. One possible interpretation of RMB's progress in import is the stable trend of appreciation for RMB during this period: foreign exporters are willing to accept RMB if it's almost certain to appreciate 3% each year.

Table 2: Currency use in trade finance, country and region

	Export			Import		
	PCP	LCP	VCP	PCP	LCP	VCP
US	**98.89%**	2.64%	0.37%	1.49%	**98.43%**	0.08%
UK	2.59%	5.21%	92.20%	7.61%	7.41%	84.98%
Germany	**47.51%**	5.26%	47.23%	2.74%	**25.18%**	72.08%
France	32.34%	2.09%	65.57%	3.91%	8.10%	88.00%
Japan	33.71%	6.43%	59.87%	9.70%	8.93%	81.37%
Canada	4.25%	8.95%	86.79%	16.19%	20.05%	63.76%
Australia	1.14%	9.35%	89.51%	8.12%	12.91%	78.97%
China	0.69%	7.10%	92.22%	10.81%	**23.22%**	65.97%
OPEC	6.35%	9.43%	84.23%	25.27%	0.67%	74.06%
OECD without US	17.67%	7.26%	75.07%	10.20%	6.20%	83.60%
Eurozone	37.90%	4.03%	58.07%	3.91%	14.37%	81.71%
World	11.98%	13.37%	74.65%	13.37%	11.98%	74.65%

Notes: Statistics calculated from sample average between 2010 October and 2014 August, using MT400 and MT700 message in SWIFT dataset. PCP for producer currency pricing; LCP for local currency pricing; VCP for vehicle currency pricing, mainly USD in this dataset. Intra Euro-zone trade excluded. Transaction among mainland China, Hong Kong, Macao, and Taiwan regarded as cross-border.

captures country's difference in financial development by $(\mathrm{FD}_i^t - \mathrm{FD}_j^t)$, measured by private credit over GDP and Chinn-Ito index.

Obviously, financial market development matters for the choice of trade settlement currency, given that private credit over GDP and Chinn-Ito index are statistically significant with the expected sign: if export country has better financial development, more of its trade would be settled in home currency[7]. More detailed description of data source and robustness tests are presented in appendix[8]. The following section would build a two-country monetary search model to emphasize the importance of financial market development in

[7]It must be cautioned here that regression significance implies correlation rather than causality. So it's safer to conclude that financial market development is a necessary but not sufficient condition for currency internationalization.

[8]One interesting observation from the regression outcome is on the behavior of distance and product differentiation. Distance is always negative and statistically significant, meaning longer distance would decrease the use of both producer currency and local currency, therefore increasing vehicle currency use. It's possible that longer distance would pose more barrier or mistrust between importer and exporter, so that vehicle currency, usually USD, would be the ultimate choice. For product differentiation, since homogeneous goods and commodity are largely denominated in USD, the trade of less differentiated tends to rely more on USD. Panel regression analysis on vehicle currency use is also presented in appendix.

Table 3: Determinants of currency use in trade, 2011-2013

	PCP			LCP		
	Total	OECD	Non-OECD	Total	OECD	Non-OECD
Market share	0.57*	2.12***	1.17***	0.50	0.87	0.77*
	(0.29)	(0.54)	(0.22)	(0.36)	(0.74)	(0.44)
Inflation	-0.00	-0.00	-0.00	-0.00*	0.01	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)
Inflation volatility	-0.01	-0.02*	-0.01	0.00	-0.01	0.02
	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)
Exchange rate	-0.08***	-0.09***	-0.01*	0.07***	0.09***	0.06***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Exchange rate volatility	0.01	-0.01	-0.01	-0.01	-0.02	-0.03**
	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)
Private credit over GDP	**0.10*** **	**0.07*** **	**0.14*** **	**-0.13*** **	**-0.31*** **	**-0.09*** **
	(0.02)	(0.03)	(0.03)	(0.02)	(0.04)	(0.03)
Capital account liberalization	**0.20*** **	**0.12*** **	0.01	**-0.17*** **	**-0.21*** **	**-0.24*** **
	(0.02)	(0.03)	(0.02)	(0.02)	(0.04)	(0.03)
Distance	-0.19***	-0.14***	-0.10***	-0.26***	-0.16***	-0.25***
	(0.02)	(0.03)	(0.02)	(0.02)	(0.03)	(0.03)
Product differentiation	0.61***	0.30***	0.41***	0.30***	0.38***	0.19***
	(0.07)	(0.10)	(0.08)	(0.06)	(0.13)	(0.07)
GDP	0.04***	-0.01	-0.03***	-0.06***	-0.06***	-0.08***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)
N	8,373	3,355	5,018	8,319	3,429	4,890
N (uncensored)	1584	1282	302	1158	409	749

Notes: Sample covers only cross-border trade. Constant omitted. US not included. The trade within Euro zone not included. The trade among mainland China, Hong Kong, and Taiwan treated as cross-border. Data frequency is annual. For dependent variable, it's the value share of PCP in column (1)-(3), and the value share of LCP in column (4)-(6). Econometric method is random-effect panel Tobit, since SWIFT dataset is restricted for confidentiality purpose: if the monthly transaction number between two countries is less than or equal to 4, its transaction value is recorded as 0. Column (1) and (4) present regression outcome for whole sample, column (2) and (5) for OECD exporter, and column (3) and (6) for non-OECD exporter. Detailed description of independent variables in appendix.

currency internationalization.

3 The Model

3.1 Environment

Time is discrete and infinite. There are two countries in the world, 1 and 2, each populated with a unit measure of buyer, seller, and investor, who live forever with a discount factor

of $\beta \in (0,1)$. Their identity is fixed over time and their respective population is σ, σ, and $(1-2\sigma)$. In addition, each country has a perfect competitive banking sector. Each period is divided into three rounds of centralized market (CM), decentralized market (DM), and financial market (FM). There is divisible and storable fiat money circulating in each country, and its total supply evolves according to $\hat{M}_i = (1+\mu_i)M_i$, where M_i is the stock of country i's fiat money in the current period, and variables with hat denote the next period's level. The growth rate of money supply, μ_i, is under central bank's control.

Here I start with brief introduction on model, and a formal description would follow. In DM, sellers are specialized in the production of a perishable[9] differentiated good q but unable to consume it, while buyers are able to consume but couldn't produce. Due to the lack of record, a medium of exchange is necessary. Moreover, q is delivered only at the beginning of next period. Assume domestic agents know each other very well so they agree on the use of open account for settlement, whereas agents from different countries don't trust each other, so settlement is facilitated by bank-intermediated finance. For international trade, buyers ask bank to issue LC, and sellers get immediate liquidity from bank after showing required document of shipment. In FM, only investors could purchase trade acceptance, which is a one-period nominal bond issued by bank, with a total payoff equal to buyer's future payment. At the beginning of next period, buyers make payment to get q, and investors receive payoff for their bond holding. In the following CM, buyer, seller, and investor engage in the production of a perishable numéraire good X and adjust their holdings of fiat money. The timing of model is depicted in figure 2.

Now I will begin to formalize the setup of physical environment. For tractability, assume the instantaneous utility function for buyer, seller, and investor in two countries is the following

$$U^B = u(q) + U(X) - H$$

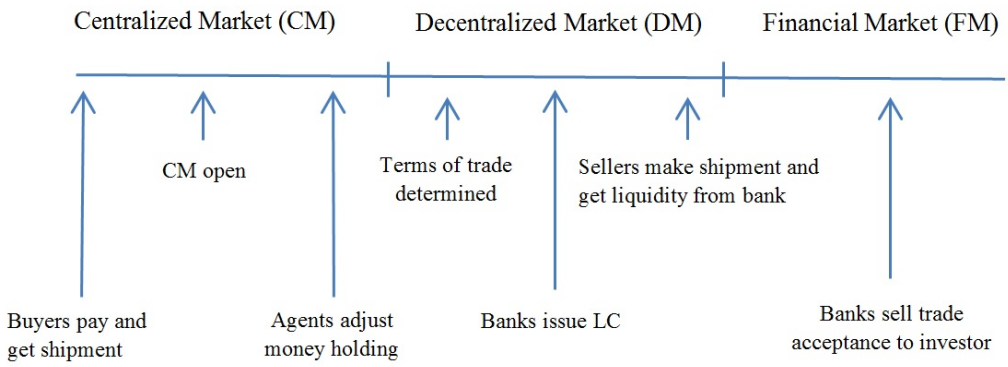
$$U^S = -c(q) + U(X) - H$$

$$U^I = U(X) - H$$

where q, X, and H capture the amount of differentiated good, numéraire good, and working hour. Although every agent could produce numéraire good with a linear technology of $X = H$, only sellers could produce differentiated good at the cost of $c(q)$. It's further assumed that the optimal consumption in CM is X^*, such that $U'(X^*) = 1$. The conventional

[9] To match the timing of this model, here I assume numéraire good is perished at the end of each period, and differentiated goods perished at the beginning of each period.

Figure 2: Model timing



assumption on function form also holds, so $u(0) = c(0) = 0, u'(0) = +\infty, c'(0) = 0, u' > 0, u'' < 0, c' > 0, c'' > 0$. For notations below, $i, j = \{1, 2\}$, $i \neq j$. The real value of country i's fiat money in terms of numéraire good is ϕ_i. This model is focused on stationary monetary equilibrium where the aggregate real balance is constant, therefore $1 + \mu_i = \frac{\phi_i}{\phi_i}$. Central banks adjust home currency supply through lump-sum transfer to domestic agent when CM opens.

There is separate DM in each country. Buyers could go abroad with a probability of $(1 - \alpha)$ while sellers stay at home. Buyer and seller meet pairwise and at random, with a matching function of $N_i = \frac{B_i S_i}{B_i + S_i}$, where N_i is the number of successful matching in country i, with B_i and S_i for the number of buyer and seller in country i's DM. With this matching function, the number of meeting between country i buyer and country j seller (n_{ij}), as well as the probability for country i buyer to meet country j seller (p_{ij}) could be determined. DM in this model functions as international trade market. FM is segmented by capital control[10]. The banking sector in country i could issue bond denominated in its home currency. The total cost (F_i) is assumed to be fixed to reflect economy of scale in financial industry. FM in this model represents financial market for short-term investment.

In contrast, CM is open to buyer, seller, and investor from both countries. This Walrasian market allows agents to adjust their holding of home and foreign currency, so it's

[10] As shown later in equilibrium, relaxing this assumption wouldn't be a big problem if there's only one international currency. For the case of LCP or LCP, different countries' interest rate might be equalized through arbitrage in FM, which would bring in indeterminacy, so I keep this capital control for simplicity.

similar to a frictionless foreign exchange market[11]. Additionally, since central bank's lump-sum transfer is applied to only domestic agents, extracting seigniorage revenue through inflation is possible only when a currency is demanded by foreigners.

The currency regime is endogenized by seller's binary choice of settlement currency [12]. If financial frictions make international trade unprofitable, international currency would never emerge. Otherwise, sellers would choose whichever currency that brings a higher level of profit.

3.2 Optimal choice and equilibrium

3.2.1 CM Value function

Agent's CM value function differs according to his type. For buyer, he would want to hold money at the end of CM to enjoy differentiated good in next period, therefore the CM maximization problem for buyer in country i is

$$W_i^B(\phi_i m_i^i, \phi_j m_j^i) = \max_{\hat{m}_i^i, \hat{m}_j^i, H, X} U(X) - H + \beta V_i^B(\hat{\phi}_i \hat{m}_i^i, \hat{\phi}_j \hat{m}_j^i)$$
$$\text{s.t.} \quad \phi_i \hat{m}_i^i + \phi_j \hat{m}_j^i + X \leq H + \phi_i m_i^i + \phi_j m_j^i + T_i$$

where m_j^i is country i buyer's holding of country j currency; V_i^B is country i buyer's value function for DM trade; T_i is the lump-sum transfer from country i central bank. This CM value function could be simplified as

$$W_i^B(\phi_i m_i^i, \phi_j m_j^i) = U(X) - X + \phi_i m_i^i + \phi_j m_j^i + T_i + \max_{\hat{m}_i^i, \hat{m}_j^i} \left\{ \beta V_i^B(\hat{\phi}_i \hat{m}_i^i, \hat{\phi}_j \hat{m}_j^i) - \phi_i \hat{m}_i^i - \phi_j \hat{m}_j^i \right\}$$

With the observation that buyer's value function is linear in his holding of money, further simplify this into

$$W_i^B(\phi_i m_i^i, \phi_j m_j^i) = W_i^B(0, 0) + \phi_i m_i^i + \phi_j m_j^i$$

For sellers, they don't have any incentive to hold money in CM since the liquidity he would get from bank is irrelevant with his holding of money. So CM value function for seller is

[11] This is certainly not without loss of generality, as discussed in Geromichalos and Jung (2015)

[12] Here I assume away the possibility that sellers accept both currencies at the same time, for two reasons. First, that doesn't happen very often in reality, given that LC is mostly issued in a single currency. Second, this assumption makes model tractable in the case of indeterminacy. In my model, sellers would choose home currency if both currencies bring the same level of positive profit. In Zhang (2014), accepting home currency doesn't incur additional information cost for seller, so accepting both currencies is possible. In this model, accepting home currency is also costly for international trade, so sellers would choose a single currency for settlement.

constant with respect to his own money holding.

With similar notations, the CM value function for country i investor is

$$W_i^I(\phi_i z_i) = \max_{\hat{z}_i, H, X} U(X) - H + \beta V_i^I(\hat{z}_i, \hat{a}_i)$$
$$\text{s.t.} \quad \phi_i \hat{z}_i + X \leq H + \phi_i z_i + T_i$$

where $V_i^I(\hat{z}_i, \hat{a}_i)$ is the value function for investor in financial market, related with his holding of home currency ($\hat{z}_i$) and trade acceptance ($\hat{a}_i$) for next period. Similarly, this value function could be simplified into

$$W_i^I(\phi_i z_i) = W_i^I(0) + \phi_i z_i$$

3.2.2 Terms of trade in DM

Buyer and seller make a proportional bargaining in DM to determine terms of trade. Buyer's utility maximization problem is

$$\max_{q, d(m)} \{u(q) - \phi d(m)\}$$

$$\text{s.t.} \quad \frac{u(q) - \phi d(m)}{\phi d(m) - \frac{c(q)}{\beta}} = \frac{\theta}{1-\theta}$$

$$d(m) \leq m$$

where q is the amount of differentiated good sellers would produce; $d(m)$ is the amount of fiat money buyers would pay to sellers; θ is buyer's bargaining power. Since buyers make payment only when q is delivered at the beginning of next period, seller's surplus is adjusted by discount factor. The solution is

$$d(m) = \begin{cases} m^* & \text{if} \quad \phi m \geq (1-\theta) u(q^*) + \theta c(q^*)/\beta \\ m & \text{if} \quad \text{otherwise} \end{cases}$$

where q^* is the level of consumption that would maximize total surplus such that $\beta u'(q^*) = c'(q^*)$; m^* is buyer's payment when total surplus is maximized, so $\phi m^* = (1-\theta)u(q^*) + \theta \frac{c(q^*)}{\beta}$. It will become clear in equilibrium that buyer's holding of fiat money would never exceed m^*, because excessive money doesn't increase his gains from trade, but would incur a loss from inflation. Therefore, buyer's payment to seller is $\phi m = (1-\theta)u(q) + \theta \frac{c(q)}{\beta}$, with

$q \leq q^*,\ \beta u'(q^*) = c'(q^*)$.

3.2.3 Investor decision in FM

Country i investor's profit maximization problem in FM is

$$\max_{a_i} \{z_i + (y_i - p_i)a_i\}$$
$$\text{s.t. } p_i a_i \leq z_i$$

where p_i and y_i are nominal price and payoff of trade acceptance issued by country i's banking sector. Notice that investor is risk-neutral since his CM value function is linear in z, so he would only want to maximize his expected level of wealth. Individual investor's demand for trade acceptance is

$$a_i = \begin{cases} 0 & \text{if } y_i < p_i \\ z_i/p_i & \text{if } y_i \geq p_i \end{cases}$$

This result is intuitive: if the payoff is lower than cost, investor's demand would be zero. For country i investor, the total demand for trade acceptance is $D = (1 - 2\sigma)a_i$. The total payoff of trade acceptance in country i should be equal to buyer's total payment for international trade settled in country i currency, so the total supply of trade acceptance is $S = \frac{s_i n_{ji} m_i^j + (1-s_j) n_{ij} m_i^i}{y_i}$.

At equilibrium, if trade acceptance is attractive to investor, its payoff must be no less than price, so $\frac{y_i}{p_i} = \frac{s_i n_{ji} m_i^j + (1-s_j) n_{ij} m_i^i}{(1-2\sigma) z_i} \geq 1$.

3.2.4 Financial constraint and seller's decision

More importantly, the addition of bank and investor imposed financial constraint for monetary equilibrium that allows for international trade. The immediate liquidity provided by bank must be able to cover seller's DM cost. Given a perfect competitive banking sector, zero profit condition holds, so this immediate liquidity is equal to the proceedings from selling trade acceptance, net of banking sector's fixed cost. Consequently, country i seller's gain from international trade settled in home currency is

$$\pi_i \equiv \left[1 - \frac{F_i}{(1-2\sigma)\phi_i z_i}\right]\left(\frac{1}{1+R_i}\right)\phi_i m_i^j - c(q_i^j)$$

where $R_i \equiv \frac{\phi_i}{\beta\phi_i} - 1$ is the nominal interest rate of country i, and q_i^j is country j buyer's purchase of differentiated good settled in country i currency[13].

From this result, seller's revenue in DM trade is affected by three factors. First, terms of trade from proportional bargaining, including $\phi_i m_i^j$ and $c(q_i^j)$. Second, discount factor of $(1+R_i)^{-1}$. Finally, financial friction influenced by the fixed cost of banking sector (F_i) and financial market liquidity of $(1-2\sigma)\phi_i z_i$. Intuitively, fixed cost is negatively correlated with seller's revenue, while an increase of financial market liquidity could help improve seller's profit from DM trade.

As shown later, inflation has negative impact on these factors at the same time. For terms of trade, higher inflation would reduce buyer's trade volume and real balance holding; for discount factor, it erodes the value of future payment; for financial friction, it tends to depress investor's confidence, thus lowering their purchase of trade acceptance. In short, higher inflation would get amplified by financial market and hugely deteriorate exporter's welfare.

Similarly, country i seller's profit from international trade settled in foreign currency is

$$\pi_i^* \equiv \left[1 - \frac{F_j}{(1-2\sigma)\phi_j z_j}\right]\left(\frac{1}{1+R_j}\right)\phi_j m_j^j - c(q_j^j)$$

With these in mind, country i sellers choose settlement currency[14].

$$\begin{cases} \text{autarky} & \text{if } \max\{\pi_i, \pi_i^*\} < 0 \\ s_i = 1 & \text{if } \max\{\pi_i, \pi_i^*\} \geq 0,\ \pi_i \geq \pi_i^* \\ s_i = 0 & \text{if } \max\{\pi_i, \pi_i^*\} \geq 0,\ \pi_i < \pi_i^* \end{cases} \quad (1)$$

Finally, currency regime comes from seller's decision. If $\{s_1, s_2\} = \{1, 0\}$ or $\{0, 1\}$, there's a single international currency (SIC); if $\{s_1, s_2\} = \{1, 1\}$, both currencies become international, and seller would use home currency for trade settlement, which is producer currency pricing (PCP); if $\{s_1, s_2\} = \{0, 0\}$, there are two international currencies, and international trade is settled by importer's home currency, which is local currency pricing (LCP). Currency regime is summarized in table 4.

[13] Here I assume the fund is equally split among exporters. Detail of derivation is in appendix.

[14] Here I didn't consider the asymmetric case when international trade is profitable for country i seller but not for country j seller, just for the sake of simplicity. It's quite easy to include that case and related discussion would be straightforward.

Table 4: Currency regime

Regime	Seller's choice	Description
SIC	$\{s_1, s_2\} = \{1, 0\}$	Country 1 currency is international
	$\{s_1, s_2\} = \{0, 1\}$	Country 2 currency is international
PCP	$\{s_1, s_2\} = \{1, 1\}$	Two international currencies Trade settled in seller's home currency
LCP	$\{s_1, s_2\} = \{0, 0\}$	Two international currencies Trade settled in buyer's home currency

3.2.5 Optimal choice for buyer and investor

For buyer and investor, the optimal holding of real balance is available after combining CM and DM value function. For country i buyer, his DM value function is

$$V_i^B = \big(p_{ii} + (1 - s_j)p_{ij}\big)\big(u(q_i^i) - \phi_i m_i^i\big) + p_{ij}s_j\big(u(q_j^i) - \phi_j m_j^i\big) + W_i^B$$

where $\big(p_{ii} + (1 - s_j)p_{ij}\big)\big(u(q_i^i) - \phi_i m_i^i\big)$ is country i buyer's expected surplus for DM trade settled in country i currency, while $p_{ij}s_j\big(u(q_j^i) - \phi_j m_j^i\big)$ is his expected surplus for trade settled in country j currency.

Substitute this into the expression of buyer's CM value function, then his maximization problem becomes

$$\max_{\hat{m}_i^i, \hat{m}_j^i} \Bigg\{ (\beta\hat{\phi}_i - \phi_i)\hat{m}_i^i + \beta\big(p_{ii} + (1 - s_j)p_{ij}\big)\theta\left[u(\hat{q}_i^i) - \frac{c(\hat{q}_i^i)}{\beta}\right]$$

$$+(\beta\hat{\phi}_j - \phi_j)\hat{m}_j^i + \beta s_j p_{ij}\theta\left[u(\hat{q}_j^i) - \frac{c(\hat{q}_j^i)}{\beta}\right]\Bigg\}$$

Several conventional observation in monetary search model would also apply here. For example, the solution for maximization problem requires $\beta\hat{\phi}_i - \phi_i < 0$ and $m < m^*$. The

first order condition for home currency is

$$R_i = (p_{ii} + (1 - s_j)p_{ij})\left[\frac{\theta(u'(q_i^i) - c'(q_i^i)/\beta)}{(1-\theta)u'(q_i^i) + \theta c'(q_i^i)/\beta}\right] \quad (2)$$

This first order condition means buyer's marginal cost of holding money (R_i) must be equal to the expected marginal benefit. Notice that buyer's demand for home currency is positive since his meeting with domestic sellers would always use home currency as medium of exchange. This is not true for foreign currency, which depends on foreign seller's decision.

$$\begin{cases} q_j^i = 0 & \text{if } \ s_j = 0 \\ \\ R_j = p_{ij}\left[\frac{\theta(u'(q_j^i) - c'(q_j^i)/\beta)}{(1-\theta)u'(q_j^i) + \theta c'(q_j^i)/\beta}\right] & \text{if } \ s_j = 1 \end{cases} \quad (3)$$

For simplicity, define $L(q) \equiv \frac{\theta(u'(q) - c'(q)/\beta)}{(1-\theta)u'(q) + \theta c'(q)/\beta}$ as liquidity premium. Apply the same procedure to investor's maximization problem, and combine the first order condition with equilibrium level of y_i/p_i, I could get investor's optimal holding of home currency.

$$\begin{cases} z_i = 0 & \text{if } \{s_i, s_j\} = \{0, 1\} \\ \\ R_i = \frac{s_i n_{ji}\phi_i m_i^j + (1-s_j)n_{ij}\phi_i m_i^i}{(1-2\sigma)\phi_i z_i} - 1, & \text{otherwise} \end{cases} \quad (4)$$

This result is also intuitive: if home currency never became international, investor wouldn't hold any of that; otherwise, investor's marginal cost of holding home currency should be equal to the rate of return from trade acceptance.

Lastly, money market should clear after agents make choice. Consider the case when international trade is profitable. $\forall i, j = \{1, 2\}, i \neq j$

$$\begin{cases} \sigma\phi_i m_i^i = \phi_i M_i & \text{if } \{s_i, s_j\} = \{0, 1\} \\ \sigma\phi_i m_i^i + (1 - 2\sigma)\phi_i z_i + F_i = \phi_i M_i & \text{if } \{s_i, s_j\} = \{0, 0\} \\ \sigma\phi_i m_i^i + \sigma\phi_i m_i^j + (1 - 2\sigma)\phi_i z_i + F_i = \phi_i M_i & \text{if } \{s_i, s_j\} = \{1, 0\}, \{1, 1\} \end{cases} \quad (5)$$

For the first case, country i currency remains national, so its demand comes from only domestic buyer. For the second case of LCP, its demand comes from home buyer, home investor, and banking sector. For the last case, home buyer, home investor, foreign buyer,

and banking sector would all demand for country i currency.

3.2.6 Monetary equilibrium of international trade

With agent's optimal choice, now it's possible to define a stationary monetary equilibrium. My main concern is the emergence of international currency, so I would focus on the equilibrium allowing for international trade.

Definition 1 *A stationary monetary equilibrium that allows for international trade is a list of time-invariant values including trade volume* $\{q_j^i\}_{i,j=1}^2$*, investor's holding of real balance* $\{\phi_i z_i\}_{i=1}^2$*, and seller's choice of settlement currency* $\{s_i\}_{i=1}^2$ *such that, given other agent's behavior,*

1. Seller's choice of $\{s_i\}_{i=1}^2$ *solves (1)*;

2. Buyer's choice of $\{q_j^i\}_{i,j=1}^2$ *solves (2)(3)*;

3. Investor's choice of $\{\phi_i z_i\}_{i=1}^2$ *solves (4)*;

4. Money market clears so that (5) holds.

3.3 Hegemony and incumbency advantage

Now consider the case of hegemony when country 1 currency becomes international while country 2 currency remains national ($s_1 = 1, s_2 = 0$). Country 1 would be referred to as center country and country 2 as peripheral country. Intuitively, country 1 buyer would never hold foreign currency since his home currency is universally acknowledged and appreciated. In contrast, country 2 buyer would hold home currency for domestic trade and foreign currency for international trade. Moreover, the single international currency makes financial market active only in country 1. Consistent with definition 1, equilibrium condition is explicitly shown in appendix. There is incumbency advantage of country 1 in this international monetary system. Due to the economy of scale in banking sector, country 2 currency would never become international without collective action, government promotion, or a sudden shock that drains financial market liquidity in country 1. This observation is summarized in proposition 1.

Proposition 1 *If country 1 currency is the only international currency, an individual seller would never use country 2 currency for international trade .*

Proof In this case, country 2 seller couldn't ask country 1 buyer to pay country 2 currency since neither buyer nor investor in country 1 holds foreign currency. For country 1 seller, if he accepted country 2 currency for trade settlement, his profit is

$$\pi_1^* \leq N \underbrace{(1-\theta)\left[u(q_2^1) - c(q_2^1)/\beta\right]}_{\text{DM surplus for seller}} - F_2,$$

where N is the number of seller trying to accept country 2 currency. If N is not sufficiently large relative to F_2, seller's profit would be negative thanks to the fixed cost in the banking sector of country 2.

Notice the difference between this incumbency advantage and the size effect emphasized by classical literature. Previous studies often argued that the size effect of large economy would help lower the transaction cost of its currency in foreign exchange market, therefore justifying its status of international currency. But proposition 1 shows that economy size alone is not enough. Financial development proves indispensable.

This situation of hysteresis leaves room for policy intervention. Government could promote the internationalization of its currency by decreasing F through financial reform or deregulation. Another possibility is for central bank to absorb financial friction by becoming market maker. In history, FED took advantage of both options after 1913, and the rise-up of US dollar was largely attributed to that, as vividly described in Eichengreen (2011).

3.4 Monetary policy and international trade

With definition 1, the equilibrium condition for SIC, PCP, and LCP could be outlined, and comparative statics on monetary policy become possible. On the part of domestic trade, monetary policy has uniform effect on agent's welfare level: higher inflation tends to reduce their gains from trade. On the part of investor, it's also easy to show that higher inflation level erodes confidence and drives down financial market liquidity. The effect of monetary policy on international trade, however, differs according to currency regimes, as shown in proposition 2.

Proposition 2 *Under some general assumptions, higher inflation of international currency would hurt whoever used it for trade settlement.*

(i) For SIC, higher inflation of international currency would hurt importer and exporter from both countries, i.e., $\frac{\partial q_1^1}{\partial R_1} < 0, \frac{\partial q_1^2}{\partial R_1} < 0, \frac{\partial \pi_1}{\partial R_1} < 0, \frac{\partial \pi_2^*}{\partial R_1} < 0$.

(ii) For PCP, higher inflation of international currency would hurt home exporter and foreign importer, i.e., $\frac{\partial \pi_1}{\partial R_1} < 0, \frac{\partial q_1^2}{\partial R_1} < 0$.

(iii) For LCP, higher inflation of international currency would hurt home importer and foreign exporter, i.e., $\frac{\partial q_1^1}{\partial R_1} < 0, \frac{\partial \pi_2^*}{\partial R_1} < 0$.

Proof in appendix

One interesting observation from proposition 2 is the relationship between nominal exchange rate and net export. This model is quite silent on exchange rate partly because, as shown in proposition 1, it's the incumbency advantage and financial development that determines the emergence of international currency. A discussion on monetary policy and international trade, however, necessitates the inclusion of exchange rate. In particular, the possibility of 'beggar thy neighbor' through nominal depreciation would influence the conduct of monetary policy. Now assume Law of One Price (LOP) for numéraire good holds in this model, and nominal exchange rate is $e_{i/j} \equiv \frac{\phi_j}{\phi_i}$, where $e_{i/j}$ is the nominal exchange rate of country i currency per country j currency[15]. Given that $\phi_i = (1 + \mu_i)\hat{\phi}_i$ in stationary monetary equilibrium, a higher inflation level of home currency would lead to nominal depreciation, whose effect on international trade differs according to currency regime.

For SIC, the result is unclear and contingent on parameter value. For PCP, higher inflation and home currency depreciation would hurt home exporter and foreign importer, thus lowering home export and net export, given that home import is insulated from this shock. For LCP, home currency depreciation would hurt home importer and foreign exporter, thus lowering home import and increasing home net export. Therefore, in this model, 'beggar thy neighbor' through nominal depreciation is possible in LCP, impossible in PCP, and uncertain in hegemony. These observations are summarized in table 5. Of course, the conduct

[15]The discussion of exchange rate in search model could be traced back to Trejos and Wright (1996), who highlighted the dominance of USD as a big reason for the out-lier performance of USD exchange rate. In appendix A.4, I revisited this topic by applying LOP to differentiated goods. The conclusion remains similar under general assumptions: as long as wholesale price is lower than retail price, the international currency would enjoy appreciation relative to national currency. Of course, the validity of LOP is always a big controversy, and it remains unclear whether LOP could be readily applied to market with searching friction.

of monetary policy is over-simplified in model. In reality, a sterilized FX intervention could depreciate home currency and stabilize money supply at the same time. A more elaborate model is required for further in-depth discussion.

Table 5: Monetary policy and international trade

	Hegemony	PCP	LCP
home importer	$\frac{\partial q_1^1}{\partial R_1} < 0$	$\frac{\partial q_2^1}{\partial R_1} = 0$	$\frac{\partial q_1^1}{\partial R_1} < 0$
home exporter	$\frac{\partial \pi_1}{\partial R_1} < 0$	$\frac{\partial \pi_1}{\partial R_1} < 0$	$\frac{\partial \pi_1^*}{\partial R_1} = 0$
foreign importer	$\frac{\partial q_1^2}{\partial R_1} < 0$	$\frac{\partial q_1^2}{\partial R_1} < 0$	$\frac{\partial q_2^2}{\partial R_1} = 0$
foreign exporter	$\frac{\partial \pi_2^*}{\partial R_1} < 0$	$\frac{\partial \pi_2}{\partial R_1} = 0$	$\frac{\partial \pi_2^*}{\partial R_1} < 0$
home net export	?	$\frac{\partial \mathrm{NX}_1}{\partial R_1} < 0$	$\frac{\partial \mathrm{NX}_1}{\partial R_1} > 0$
foreign net export	?	$\frac{\partial \mathrm{NX}_2}{\partial R_1} > 0$	$\frac{\partial \mathrm{NX}_2}{\partial R_1} < 0$

Notes: Country 1 is regarded as home country. In the first column, country 1 currency emerged as the single international currency. For the second column, international trade is settled by seller's home currency. For the last column, international trade is settled by buyer's home currency.

3.5 Welfare analysis and optimal monetary policy

A prominent advantage of monetary search model is the tractability of agent's asset holding and welfare level, which is important for the conduct of optimal monetary policy if central bank is assumed to maximize the social welfare of its own country. In this model, social welfare consists of seigniorage revenue, gains from trade, and a loss from banking sector's fixed cost if this country issues international currency. For simplicity, additional welfare gain from consuming numéraire good is omitted.

If country 1 issues the only international currency, for example, social welfare level at

the end of each period is the following.

$$W_1 = \underbrace{\mu_1\sigma\phi_1 m_1^2}_{\text{Seigniorage revenue}} + \underbrace{n_{11}\big[\beta u(q_1^1) - c(q_1^1)\big]}_{\text{domestic trade surplus}} + \underbrace{n_{12}\theta\big[\beta u(q_1^1) - c(q_1^1)\big]}_{\text{importer surplus}}$$
$$+ \underbrace{n_{21}\Big\{\big[1 - \frac{F_1}{(1-2\sigma)\phi_1 z_1}\big]\big(\frac{1}{1+R_1}\big)\phi_1 m_1^2 - c(q_1^2)\Big\}}_{\text{exporter surplus}} - F_1$$

$$W_2 = -\mu_1\sigma\phi_1 m_1^2 + n_{22}\big[\beta u(q_2^2) - c(q_2^2)\big] + n_{21}\theta\big[\beta u(q_1^2) - c(q_1^2)\big]$$
$$+ n_{12}\Big\{\big[1 - \frac{F_1}{(1-2\sigma)\phi_1 z_1}\big]\big(\frac{1}{1+R_1}\big)\phi_1 m_1^1 - c(q_1^1)\Big\}$$

With similar procedure, the welfare level for PCP and LCP is shown in appendix.

From previous assumptions and proposition 2, each country's gain from international trade is decreasing in the nominal interest rate of international currency. For seigniorage revenue, recall that central bank's lump-sum transfer is applied to only domestic agent, and other agents need to purchase that currency in CM. Therefore, seigniorage revenue is possible only when there's foreign demand for that country's currency. Without loss of generality, assume seigniorage revenue is increasing in the growth rate of money supply, which gives incentive to deviate from Friedman rule.

Seigniorage revenue would cancel out in the summation of each country's welfare, so Friedman rule is optimal for a social planner trying to maximize total welfare. In addition, it's inefficient to issue two international currencies since that would incur fixed cost of banking sector in both countries. Social planner would let a country with lower F issue a single international currency. For each country aimed at maximizing its own welfare, Friedman rule is not optimal if there's foreign demand of its currency, which includes the case of PCP and hegemony when a country issues the only international currency. These observations are summarized in proposition 3.

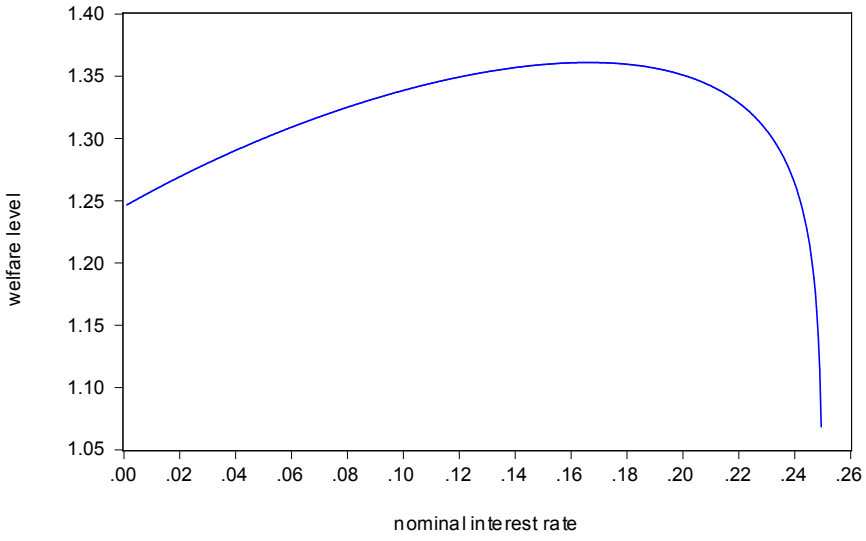
Proposition 3 *In a stationary monetary equilibrium with international trade, Friedman rule of zero nominal interest rate is not always optimal.*

1. For social planner trying to maximize total welfare, Friedman rule is optimal, and countries with higher degree of financial development would issue international currency.

2. For central bank trying to maximize the social welfare of its own country, Friedman rule is not optimal when there's is foreign demand of its currency.

Figure 3 shows the second case of central bank facing trade off between seigniorage revenue and gains from trade. It plots the relationship between nominal interest rate and the welfare level of a country that issues the only international currency. For illustration, the function form is borrowed from Lagos and Wright (2005) with $u(q) = ln(q+b) - ln(q)$, $c(q) = q$, $b = 0.0001$. Additionally, $\alpha = 0.5$, $\beta = 0.966$, $\sigma = 0.3$, $\theta = 0.5$, $F = 0.01$. Friedman rule is clearly not optimal, since the welfare level is maximized around 16% of nominal interest rate. Also, the status of international currency would be lost if nominal interest rate is raised above 25%, putting a limit central bank's conduct of monetary policy, which has been intensively discussed in Zhang (2014).

Figure 3: Optimal monetary policy



One interpretation of proposition 3 is to regard international currency as public good, in the spirit of Kindleberger (1986). Center country makes investment in banking sector and financial institution to facilitate trade. Peripheral country takes advantage of international currency as well as the system of payment and settlement. Seigniorage revenue conveys negative externality since center country tends to inflate and overproduce international

currency, and that would hurt the rest of world. For a social planner, that externality is internalized and canceled out, retaining Friedman rule as the optimal monetary policy.

4 Discussion of related topics

4.1 Size effect revisited

Classical and recent literature uniformly favored large economy as provider of international currency due to the size effect. For example, Devereux and Shi (2013) built a DSGE model for quantitative analysis, and concluded that large country is in a good position to provide international currency, since large trade volume would reduce transaction cost in FX market. In what follows I would use a numerical example to re-evaluate this issue.

In my model, economy size is approximated by national population, i.e., the total number of buyer, seller, and investor. A change in population would, according to matching function, directly influence the number and probability of the meeting between buyer and seller, thus affecting equilibrium outcome. Figure 4 shows the relationship for center country's population and its optimal nominal interest rate. Parameter value and function forms are identical to those in figure 3. Center country's population is ranged from 0.1 to 10, while peripheral country's population stays at 1. A hump-shape is surprising at first sight, but the decomposition of center country's welfare in figure 5 demystifies everything. In essence, size effect alters the degree of trade-off between seigniorage revenue and gains from trade. For a large economy, gains from domestic trade dominate its total welfare, so higher inflation is not a good choice. Similarly, gains from international trade makes up the biggest part of welfare for a small open economy, reducing the attractiveness of reaping seigniorage revenue. It's therefore reasonable to think of figure 4 as a continuation of proposition 3 in exploration of center country's optimal monetary policy. Size effect is crucial here not because of its absolute value, but in affecting the desirability of seigniorage revenue: if gains from trade loom larger and larger from size effect, convergence to Friedman rule becomes a better choice. In other words, it is the share of gains from trade in its total welfare that determines whether a country is qualified as natural provider of international currency.

To summarize, hegemony is reasonable for a unipolar world dominated by economic superpower, while multiple international currencies make sense in a multipolar world with evenly distributed economy size.

Figure 4: Size effect

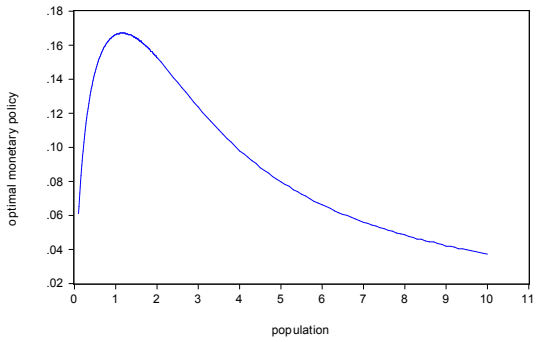
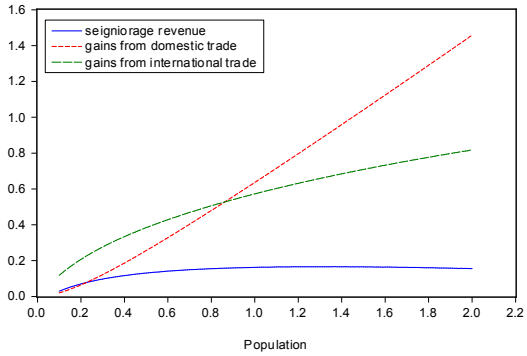


Figure 5: Welfare decomposition



4.2 Global imbalance

The 2008 financial crisis brought into attention the huge trade deficit of United States, known as global imbalance now. Many studies regard it as transitory phenomenon due to the saving glut of Asian countries (Bernanke, 2005) or the monetary policies of United states and exchange rate policy of emerging countries (Obstfeld and Rogoff, 2009). My model of international currency, however, illustrates that global imbalance is a sustainable and structural symptom arising from the arrangement of monetary system. If there's only a single international currency, the center country would have trade deficit at equilibrium in a perfect symmetric model, whereas multiple international currencies would help reduce this global imbalance[16].

Now consider a perfect symmetric two country model where both countries are identical in size, openness, and monetary policy, so that $n_{12} = n_{21},\ p_{12} = p_{21},\ p_{11} = p_{22},\ R_1 = R_2 > 0$. If country 1 issues the only international currency, equilibrium condition indicates

$$R_1 = (p_{11} + p_{12})L(q_1^1) = p_{21}L(q_1^2),$$

which naturally leads to the observation that $q_1^1 > q_1^2$, given $p_{11} + p_{12} > p_{21}$ and $L'(q) < 0$. From terms of trade, $\phi m = (1-\theta)u(q) + \theta\frac{c(q)}{\beta}$, so $\phi_1 m_1^1 > \phi_1 m_1^2$. Intuitively, country 1 buyer would hold more real balance of country 1 currency since he expects a higher chance

[16]Here I focus on trade deficit because there's capital control in model, so the current account of both countries should be zero. Relaxing capital control and considering only one international currency, the trade deficit here naturally transforms into current account deficit. Also notice that, in this simple model with no capital account transaction, fiat money is included in current account.

of meeting with home or foreign seller, while country 2 buyer would hold less real balance of international currency since his trade with home sellers is still settled in country 2 currency. The trade balance for country 1 is therefore

$$\mathrm{TB}_1 \equiv \mathrm{EX}_1 - \mathrm{IM}_1 = n_{21}q_1^2 - n_{12}q_1^1 < 0.$$

Obviously, even in a perfect symmetric model, the single issuing country of international currency would have persistent trade deficit, which doesn't hold for other currency regimes. In PCP,

$$\begin{cases} R_1 = p_{11}L(q_1^1) = p_{21}L(q_1^2) \\ R_2 = p_{12}L(q_2^1) = p_{22}L(q_2^2) \end{cases}$$

With $q_1^2 = q_2^1$, trade balance of both countries is zero. Similarly for LCP

$$\begin{cases} R_1 = (p_{11} + p_{12})L(q_1^1) \\ R_2 = (p_{22} + p_{21})L(q_2^2) \end{cases}$$

With $q_1^1 = q_2^2$, trade balance is also zero for both countries. This finding echoes Liu and Zhou (2015), who built a DSGE model to show the sustainability of US current account deficit resulting from the status of dollar as an international currency[17].

It should be cautioned here this model doesn't provide any normative analysis on global imbalance, since agents would always benefit from international trade, irrelevant with current account surplus or deficit. So this application only states that a system of multiple international currencies is desirable if global imbalance proves problematic.

The case of asymmetric model is complicated and sensitive to parameter value. For simplicity, the following discussion is limited to the case of hegemony where country 1 issues the only international currency. First consider the effect of monetary policy. Differentiate the trade balance of country 1 with respect to the nominal interest rate of country 1, and the result follows.

$$\frac{\partial \mathrm{TB}_1}{\partial R_1} = \frac{1}{R_1}\left[\frac{\mathrm{EX}_1}{\epsilon_L(q_1^2)} - \frac{\mathrm{IM}_1}{\epsilon_L(q_1^1)}\right], \quad \epsilon_L(q) \equiv \frac{\partial L}{\partial q}\frac{q}{L}$$

[17]The mechanism of their model is quite different from mine. Like most invoicing currency model, they presumed CIA to introduce fiat money. US dollar is also exogenously assumed to be the only international currency. US trade deficit is determined by foreign demand of dollar. With positive long-run growth of global economy, there would be a structural global imbalance, whose magnitude is affected by the degree of openness, substitution elasticity between home and foreign goods, and the relative size of US economy to the rest of world.

From this, the effect of monetary policy on current account is crucially dependent on the elasticity of liquidity premium and trade volume: if $\frac{\mathrm{EX}_1}{\epsilon_L(q_1^2)} > \frac{\mathrm{IM}_1}{\epsilon_L(q_1^1)}$, higher level of interest rate would deteriorate center country's current account, otherwise inflation would help reduce global imbalance. Next consider country size effect, illustrated in figure 6 and 7 with numerical example. Both figures plot the relationship between the population and current account of the country that issues the only international currency. The function form and parameter value still follows those in figure 3, with the only exception of α that represents preference shock. The level of nominal interest rate is welfare-maximizing. With a low level of α, as in figure 6, there's no monotone relationship between country size and trade balance, whereas global imbalance deepened with population when α is relatively high in figure 7.

Figure 6: Asymmetric case: $\alpha = 0.2$

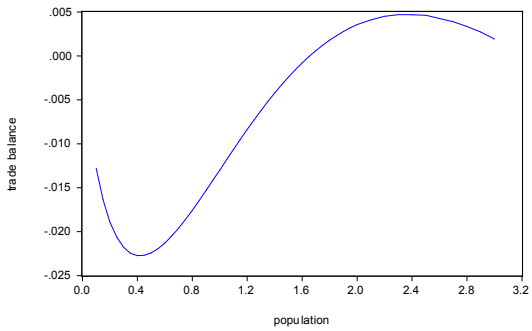
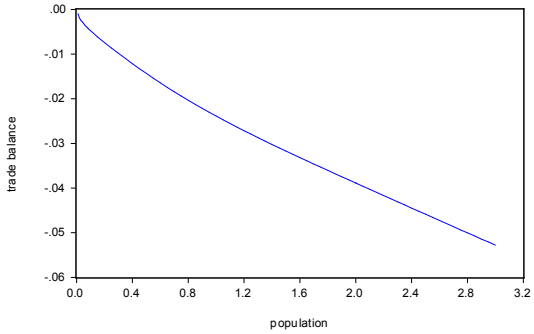


Figure 7: Asymmetric case: $\alpha = 0.5$



4.3 International vehicle currency

The model could be easily extended into N-country case to account for the emergence of IVC. Model details and equilibrium conditions are derived in appendix for 3-country model. Here I would show a main finding from model implication: sellers in different countries would choose the same settlement currency for the export to a certain country, as long as they are identical in bargaining power and cost function. In other words, sellers display herding behavior in their choice of settlement currency.

Consider country j seller's profit from trade with country i buyer, settled in country k

currency, and its expression follows.

$$\pi_{ij}^{k} = \left(1 - \frac{F_k}{(1-2\sigma)\phi_k z_k}\right)\frac{1}{1+R_k}\phi_k m_k^i - c_j(q_k^i)$$

Notice that seller's feature would influence only terms of trade and cost function: higher level of bargaining power brings in better terms of trade, and efficient production improves profitability. If sellers are identical in these two aspects, their profit would be equal for the export to a certain country, which leads to the rise of a common IVC to reduce financial friction. Therefore, exporter of commodity or homogeneous good would choose the same currency for settlement, which is consistent with empirical literature. Goldberg and Tille (2008) showed that US dollar is the dominant invoicing currency for the international trade of commodity and homogeneous goods[18].

5 Concluding remarks

China has been trying to internationalize RMB since great recession, and several measures are taken to accelerate this process, including currency swap agreement, offshore market development, cross-border trade settlement, and capital account liberalization. Among these, trade settlement is a natural starting point given China's leading role in merchandise trade. In contrast with traditional view of thick market externality and natural monopoly, recent literature highlighted the importance of a deep and liquid financial market. In this paper, I verified this finding with SWIFT trade finance data, and built a two-country monetary search model to discuss the determinants of international currency. This illustrative model also emphasized government's role in taking initiative to foster market, and explored the conduct of monetary policy in different regimes. For future research, modeling financial market in a more meaningful way is desirable for asset pricing as well as the impact of capital account liberalization.

RMB's recent success in joining SDR basket reaffirmed China's grand plan of financial reform and deregulation, although the outcome of such bold action remains uncertain, especially given the recent chaos in stock market. A monetary system with multiple international currencies is beneficial to United States long accused of exorbitant privilege, as well as peripheral countries often criticized for excessive reserve accumulation. Whether RMB is a qualified candidate in this race to new world, we shall wait and see.

[18]Their explanation for this phenomenon is different. They argued that commodity price shows excessive volatility, and IVC is used to reduce exchange rate risk.

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A Appendix

A.1 Equilibrium condition of different currency regimes

According to definition 1, the equilibrium condition for country 1 currency to emerge as the single international currency is the following.

For buyer

$$\begin{cases} R_1 = (p_{11} + p_{12})L(q_1^1) = p_{21}L(q_1^2) & (1.1) \\ R_2 = p_{22}L(q_2^2) & (1.2) \end{cases}$$

For seller

$$\begin{cases} \pi_1 = \left[1 - \frac{F_1}{(1-2\sigma)\phi_1 z_1}\right]\left(\frac{1}{1+R_1}\right)\phi_1 m_1^2 - c(q_1^2) > 0 & (1.3) \\ \pi_2^* = \left[1 - \frac{F_1}{(1-2\sigma)\phi_1 z_1}\right]\left(\frac{1}{1+R_1}\right)\phi_1 m_1^1 - c(q_1^1) > 0 & (1.4) \end{cases}$$

For investor

$$R_1 = \frac{n_{1,2}\phi_1 m_1^1 + n_{2,1}\phi_1 m_1^2}{(1-2\sigma)\phi_1 z_1} - 1 \quad (1.5)$$

For money market

$$\begin{cases} \sigma\phi_1 m_1^1 + \sigma\phi_1 m_1^2 + (1-2\sigma)\phi_1 z_1 + F_1 = \phi_1 M_1 & (1.6) \\ \sigma\phi_2 m_2^2 = \phi_2 M_2 & (1.7) \end{cases}$$

If equations (1.1)-(1.8) are satisfied at the same time, country 1 currency would emerge as the only international currency. Similarly, the equilibrium condition for PCP is the following.

For buyer

$$\begin{cases} R_1 = p_{11}L(q_1^1) = p_{21}L(q_1^2) & (2.1.1) \\ R_2 = p_{12}L(q_2^1) = p_{22}L(q_2^2) & (2.1.2) \end{cases}$$

For seller

$$\begin{cases} \pi_1 > 0,\ \pi_1 > \pi_1^* & (2.1.3) \\ \pi_2 > 0,\ \pi_2 > \pi_2^* & (2.1.4) \end{cases}$$

For investor

$$\begin{cases} R_1 = \frac{n_{21}\phi_1 q_1^2}{(1-2\sigma)\phi_1 z_1} - 1 & (2.1.5) \\ R_2 = \frac{n_{12}\phi_2 q_2^1}{(1-2\sigma)\phi_2 z_2} - 1 & (2.1.6) \end{cases}$$

For money market

$$\begin{cases} \sigma\phi_1 m_1^1 + \sigma\phi_1 m_1^2 + (1-2\sigma)\phi_1 z_1 + F_1 = \phi_1 M_1 & (2.1.7) \\ \sigma\phi_2 m_2^2 + \sigma\phi_2 m_2^1 + (1-2\sigma)\phi_2 z_2 + F_2 = \phi_2 M_2 & (2.1.8) \end{cases}$$

For LCP, equilibrium condition is the following.

For buyer

$$\begin{cases} R_1 = (p_{11} + p_{12})L(q_1^1) & (2.2.1) \\ R_2 = (p_{22} + p_{21})L(q_2^2) & (2.2.2) \end{cases}$$

For seller

$$\begin{cases} \pi_1^* > 0 & (2.2.3) \\ \pi_2^* > 0 & (2.2.4) \end{cases}$$

For investor

$$\begin{cases} R_1 = \frac{n_{12}\phi_1 q_1^1}{(1-2\sigma)\phi_1 z_1} - 1 & (2.2.5) \\ R_2 = \frac{n_{21}\phi_2 q_2^2}{(1-2\sigma)\phi_2 z_2} - 1 & (2.2.6) \end{cases}$$

For money market

$$\begin{cases} \sigma\phi_1 m_1^1 + (1-2\sigma)\phi_1 z_1 + F_1 = \phi_1 M_1 & (2.2.7) \\ \sigma\phi_2 m_2^2 + (1-2\sigma)\phi_2 z_2 + F_2 = \phi_2 M_2 & (2.2.8) \end{cases}$$

A.2 Deriving exporter's profit function

Here I would derive exporter's profit function in section 3.2.4. First, without the friction of trade finance, country i exporter's profit from international trade with country j buyer is

$$\phi_i m_i^j - c(q_i^j)$$

Now with trade finance, exporter's actual profit also depends on the ratio of investor's fund and buyer's payment, assuming each seller would get the same level of liquidity from

bank. For simplicity, the international trade is here assumed to be settled in country i currency.

Investor's fund channeled to exporter, net of banking sector's fixed cost, is

$$(1-2\sigma)\phi_i z_i - F_i$$

Country j buyer's total payment to country i exporter is $n_{ji}\phi_i m_i^j$. From investor's equilibrium condition derived in section 3.2.5, the rate of return investors hope to get from bond should be able to compensate the loss from inflation, so that, in this special case,

$$R_i = \frac{n_{ji}\phi_i m_i^j}{(1-2\sigma)\phi_i z_i} - 1$$

With the above equations, it's possible to simplify the ratio between investor and buyer's fund

$$\frac{(1-2\sigma)\phi_i z_i - F_i}{n_{ji}\phi_i m_i^j} = \frac{(1-2\sigma)\phi_i z_i - F_i}{(1+R_i)(1-2\sigma)\phi_i z_i} = \left\{1 - \frac{F_i}{(1-2\sigma)\phi_i z_i}\right\}\left(\frac{1}{1+R_i}\right)$$

Therefore, seller's actual profit from international trade is

$$\pi_i \equiv \left\{1 - \frac{F_i}{(1-2\sigma)\phi_i z_i}\right\}\left(\frac{1}{1+R_i}\right)\phi_i m_i^j - c(q_i^j)$$

Of course, this equation should be written in a less interesting manner

$$\pi_i = \frac{(1-2\sigma)\phi_i z_i - F_i}{n_{ji}} - c(q_i^j)$$

which just says exporters equally split investor's fund.

For extension, if capital account is open and investors are allowed to buy foreign bond, the reasoning here would hold, and the specific expression of seller's profit is

$$\pi_i \equiv \left\{1 - \frac{F_i}{(1-2\sigma)\phi_i z_i + (1-2\sigma)\phi_i z_i^j}\right\}\left(\frac{1}{1+R_i}\right)\phi_i m_i^j - c(q_i^j)$$

where $\phi_i z_i^j$ is the real balance holding by foreign investors. Obviously, larger market liquidity would help reduce transaction cost.

A.3 Proof of proposition 2

Most of this proof is straightforward except the part of exporter's gain from international trade, which requires additional assumption on function form.

Lemma 1 *If exporter's financial loss is more sensitive than DM cost function in resonse to interest rate shock, i.e.,* $(\epsilon_f + \epsilon_c) > 0$ *, exporter's gain from international trade is decreasing in nominal interest rate, i.e.,* $\frac{\partial \pi}{\partial R} < 0$.

Proof Let $\beta^E \equiv (1 - \frac{F}{(1-2\sigma)\phi z})(1+R)^{-1}$ denote the effective discount factor for seller. Without loss of generality, assume $\beta^E < \beta$ so that financial friction would reduce seller's gain from trade. Therefore, $(\beta - \beta^E) > 0$ is a measure of seller's financial loss. Combine the expression of buyer's payment in DM and seller's profit in section (3.2.4), I could get

$$\pi = \beta^E(1-\theta)\left[u(q) - \frac{c(q)}{\beta}\right] - \frac{1}{\beta}(\beta - \beta^E)c(q).$$

Given that $\frac{\partial \phi z}{\partial R} < 0$, it's easy to find that $\frac{\partial \beta^E}{\partial R} < 0$. With the previous condition in proportional bargaining, $q < q^*,\ u'(q*) = \frac{c'(q^*)}{\beta},\ u' < 0,\ c' > 0$, the first item is decreased in R.

For the second item, differentiate with respect to R, I could get $\frac{cf}{\beta R}(\epsilon_f + \epsilon_c)$, where $f \equiv (\beta - \beta_E)$ captures the degree of seller's financial loss, $\epsilon_f \equiv \frac{\partial f}{\partial R}\frac{R}{f}$ is the elasticity of financial loss on nominal interest rate. Similarly, ϵ_c is the elasticity of seller's DM cost in response to interest rate shock. Obviously, $\epsilon_f > 0, \epsilon_c < 0$. A sufficient condition for $\frac{\partial \pi}{\partial R} < 0$ is $\epsilon_f + \epsilon_c > 0$. Therefore, as long as financial loss is more sensitive to the change of nominal interest rate, higher inflation level would decrease exporter's gain from international trade.

Another helpful observation is the property of buyer's liquidity premium. Recall its definition.

$$L(q) \equiv \frac{\theta(u'(q) - \frac{c'(q)}{\beta})}{(1-\theta)u'(q) + \theta\frac{c'(q)}{\beta}}$$

Take differentiation with respect to q, I could get the following result.

$$L'(q) = \frac{\theta}{\beta}\left[(1-\theta)u'(q) + \frac{\theta}{\beta}c'(q)\right]^{-2}(u''c' - u'c'')$$

With previous assumption on function form, $u' > 0, c' > 0, u'' < 0, c'' > 0$, it's obvious

that $L'(q) < 0$, so buyer's liquidity premium is decreasing in his trade volume. After these preparations, now it's easy to prove proposition 2.

Proof of Proposition 2

On the part of exporters, assume $\epsilon_f + \epsilon_c > 0$ always holds.

For single international currency

$$\begin{cases} \frac{\partial q_1^1}{\partial R_1} = ((p_{11} + p_{12})L'(q_1^1))^{-1} < 0 \\ \frac{\partial q_1^2}{\partial R_1} = (p_{21}L'(q_1^1))^{-1} < 0 \end{cases} \quad \begin{cases} \frac{\partial \pi_1}{\partial R_1} < 0 \\ \frac{\partial \pi_2^*}{\partial R_1} < 0 \end{cases}$$

For PCP

$$\begin{cases} \frac{\partial q_2^1}{\partial R_1} = 0 \\ \frac{\partial q_1^2}{\partial R_1} = (p_{21}L'(q_1^2))^{-1} < 0 \end{cases} \quad \begin{cases} \frac{\partial \pi_1}{\partial R_1} < 0 \\ \frac{\partial \pi_2}{\partial R_1} = 0 \end{cases}$$

For LCP

$$\begin{cases} \frac{\partial q_2^1}{\partial R_1} = ((p_{11} + p_{12})L'(q_1^1))^{-1} < 0 \\ \frac{\partial q_2^2}{\partial R_1} = 0 \end{cases} \quad \begin{cases} \frac{\partial \pi_1^*}{\partial R_1} = 0 \\ \frac{\partial \pi_2^*}{\partial R_1} < 0 \end{cases}$$

A.3.1 Welfare level

For PCP, the welfare level is the following.

$$\begin{aligned} W_1 =& \underbrace{\mu_1\sigma\phi_1 m_1^2 - \mu_2\sigma\phi_2 m_2^1}_{\text{Seigniorage revenue}} + \underbrace{n_{11}\big[\beta u(q_1^1) - c(q_1^1)\big]}_{\text{domestic trade surplus}} + \underbrace{n_{12}\theta\big[\beta u(q_2^1) - c(q_2^1)\big]}_{\text{importer surplus}} \\ &+ \underbrace{n_{21}\left\{\big[1 - \frac{F_1}{(1-2\sigma)\phi_1 z_1}\big]\big(\frac{1}{1+R_1}\big)\phi_1 m_1^2 - c(q_1^2)\right\}}_{\text{exporter surplus}} - F_1 \end{aligned}$$

$$\begin{aligned} W_2 =& \mu_2\sigma\phi_2 m_2^1 - \mu_1\sigma\phi_1 m_1^2 + n_{22}\big[\beta u(q_2^2) - c(q_2^2)\big] + n_{21}\theta\big[\beta u(q_1^2) - c(q_1^2)\big] \\ &+ n_{12}\left\{\big[1 - \frac{F_2}{(1-2\sigma)\phi_2 z_2}\big]\big(\frac{1}{1+R_2}\big)\phi_2 m_2^1 - c(q_2^1)\right\} - F_2 \end{aligned}$$

For LCP, welfare level is the following.

$$W_1 = \underbrace{n_{11}\big[\beta u(q_1^1) - c(q_1^1)\big]}_{\text{domestic trade surplus}} + \underbrace{n_{12}\theta\big[\beta u(q_1^1) - c(q_1^1)\big]}_{\text{importer surplus}} + \underbrace{n_{21}\Big\{\big[1 - \frac{F_2}{(1-2\sigma)\phi_2 z_2}\big]\big(\frac{1}{1+R_2}\big)\phi_2 m_2^2 - c(q_2^2)\Big\}}_{\text{exporter surplus}} - F_1$$

$$W_2 = n_{22}\big[\beta u(q_2^2) - c(q_2^2)\big] + n_{21}\theta\big[\beta u(q_2^2) - c(q_2^2)\big] + n_{12}\Big\{\big[1 - \frac{F_1}{(1-2\sigma)\phi_1 z_1}\big]\big(\frac{1}{1+R_1}\big)\phi_2 m_1^1 - c(q_1^1)\Big\} - F_2$$

A.4 Determinants of exchange rate in search model

In search model, the determinants of nominal exchange rate depends on the law of one price. In previous study, the law of one price is assumed to hold only for numéraire good, so that its price denominated in different currencies should be the same. This implies

$$\frac{1}{\phi_i} = \frac{1}{\phi_j} e_{i/j} \quad \forall i, j \in \{1, 2\},\ i \neq j$$

where $e_{i/j}$ is the nominal exchange rate of country i currency against country j currency, with its increase indicating a relative appreciation of country j currency and depreciation of country i currency. The assumption of law of one price for numéraire good is reasonable, since it's traded in CM, which is a Walrasian market allowing for arbitrage and equalized price. The determinants of exchange rate ($e_{i/j} = \phi_j/\phi_i$) are totally based on currency value, under the control of central banks: a higher level of inflation leads to value decrease and currency depreciation. This fundamental-based determinant, however, couldn't explain exchange rate dynamics to a satisfactory degree. The well-known exchange rate disconnection puzzle revealed the poor performance of such models in forecasting and prediction. In this part, I would revisit the determinants of exchange rate in search model, by applying the law of one price to differentiated good.

Search theory has a long history of discussing international currency and exchange rate. Previous studies used second-generation search model to show that the status of international currency gives USD more purchasing power, which could explain why the

exchange rate of USD is an out-lier according standard theory. Here I would continue this discussion with my two-country third-generation search model. Since DM in my model is segmented by border, the law of one price would only be applied to the differentiated good originating from the same country. For all the discussion below, $\forall i, j \in \{1, 2\},\ i \neq j$.

A.4.1 Producer Currency Pricing, PCP

In a world of PCP where the international trade is settled by exporter's home currency, the law of one price for differentiated good couldn't be applied. For the differentiated good in country i, if country i seller meets country i buyer, the domestic trade is settled by country i currency at the price level of m_i^i/q_i^i; if country i seller meets country j buyer, the export is still denominate by country i currency, only at a different price level of m_i^j/q_i^j. So here's one good with two prices, but denominated in the same currency. So it's proper to interpret this as price discrimination due to searching friction.

A.4.2 Local Currency Pricing, LCP

In a world of LCP where the international trade is settled by importer's home currency, the law of one price could be applied. For the differentiated good in country i, if country i seller meets country i buyer, the domestic trade is settled by country i currency, at the price level of m_i^i/q_i^i; if country i seller meets country j buyer, the country would be settled by country j currency at the price level of m_j^j/q_j^j. Here's one good denominated in different currencies at different price levels. If the law of one price holds, the determinant equation for exchange rate is

$$\frac{1}{\phi_i}\frac{\phi_i m_i^i}{q_i^i} = \frac{1}{\phi_j}\frac{\phi_j m_j^j}{q_j^j} e_{i/j} \Rightarrow e_{i/j} = \left(\frac{\phi_j}{\phi_i}\right)\left(\frac{\phi_i m_i^i/q_i^i}{\phi_j m_j^j/q_j^j}\right) \Rightarrow e_{i/j} = \left(\frac{\phi_j}{\phi_i}\right)\left\{\frac{[(1-\theta)u(q_i^i) + \theta c(q_i^i)/\beta]/q_i^i}{[(1-\theta)u(q_j^j) + \theta c(q_j^j)/\beta]/q_j^j}\right\}$$

The last step of derivation used the DM bargaining solution for buyer's payment. In contrast to the fundamental-based determinants of exchange rate, the equation above also incorporates the relative searching friction.

$$e_{i/j} = \underbrace{\left(\frac{\phi_j}{\phi_i}\right)}_{\text{monetary policy}} \underbrace{\left\{\frac{[(1-\theta)u(q_i^i) + \theta c(q_i^i)/\beta]/q_i^i}{[(1-\theta)u(q_j^j) + \theta c(q_j^j)/\beta]/q_j^j}\right\}}_{\text{Relative searching friction}}$$

To further discuss the impact of searching friction on exchange rate, it's necessary to make reasonable assumption on the function form of utility and cost.

Assumption 1 *The average price of differentiated good is decreasing in trade volume, i.e.* $\partial(\phi m/q)/\partial q < 0$. *Given the DM bargaining solution for buyer's the payment, this is equivalent to* $(1-\theta)u'(q) + \theta c'(q)/\beta < 1$.

This assumption is also consistent with the daily experience that wholesale price is normally lower than retail price. Now it's possible to discuss the impact of searching friction on exchange rate.

Proposition 4 *All else equal, the currency with a lower level of searching friction would experience nominal appreciation.*

Proof Consider the first order condition for country i buyer's optimal currency holding

$$R_i = (p_{ii} + p_{ij})L(q_i^i)$$

In this case, lower searching friction means a higher level of matching probability. Therefore, the following result could be derived at a given nominal interest rate.

$$(p_{ii} + p_{jj}) \uparrow \Rightarrow L(q_i^i) \downarrow \Rightarrow q_i^i \uparrow \Rightarrow (\phi_i m_i^i/q_i^i) \downarrow \Rightarrow \left(\frac{\phi_j}{\phi_i}\right)\left(\frac{\phi_i m_i^i/q_i^i}{\phi_j m_j^j/q_j^j}\right) \downarrow \Rightarrow e_{i/j} \downarrow$$

Along this line of derivation, the second step utilized the property of liquidity premium, and the fourth step is from assumption 1. Intuitively, less searching friction leads to better matching probability, and increased trade volume improves the purchasing power of currency, with nominal appreciation as a result.

A.4.3 Single international currency in symmetric case

If country i currency becomes the single international currency to settle trade, it's PCP for country i and LCP for country j. Given our discussion above, the law of one price could be applied to only country j differentiated good.

$$\frac{1}{\phi_i}\frac{\phi_i m_i^i}{q_i^i} = \frac{1}{\phi_j}\frac{\phi_j m_j^j}{q_j^j} e_{i/j} \Rightarrow e_{i/j} = \left(\frac{\phi_j}{\phi_i}\right)\left(\frac{\phi_i m_i^i/q_i^i}{\phi_j m_j^j/q_j^j}\right)$$

Assume a symmetric case in which two countries are identical in every aspect other than that country i issues the only international currency. In this situation, similar to the discussion on global imbalance, country i residents have better chance to get matched so they hold more currency and consume more. According to proposition 4, international currency normally enjoys appreciation, i.e.,

$$q_i^i > q_j^j \Rightarrow e_{i/j} < 1$$

A.5 Three-country model

The potential payment system in three-country model is quite numerous, and this part is concerned about the rise of international vehicle currency (IVC), which is used to settle trade between non-issuing countries. The assumption in two-country model could be easily applied here, requiring only minor change of notation. $\forall i, j, k \in 1, 2, 3$, p_{ij} is the probability of successful matching between country i buyer and country j seller; n_{ij} is the corresponding number of meeting; q_j^i is country i buyer's holding of country j currency; π_{ij}^k is country j seller's profit from his trade with country i buyer, settled in country k currency. Most importantly, here I assume sellers in different countries are identical in bargaining power and cost function, so that the consistency from proposition 4 would hold. For simplicity, the following discussion covers only the case of single and double international currency.

A.5.1 Single dominance

Now consider a case of hegemony in three-country model, assuming country 1 issues the only international currency. Figure 8 shows the payment system in this case, where all the international trade is settled in country 1 currency. The following equilibrium condition is in order.

For buyer

$$\begin{cases} R_1 = (p_{11} + p_{12} + p_{13})L(q_1^1) = (p_{21} + p_{23})L(q_1^2) = (p_{31} + p_{32})L(q_1^3) & (3.1.1) \\ R_2 = p_{22}L(q_2^2) & (3.1.2) \\ R_3 = p_{33}L(q_3^3) & (3.1.3) \end{cases}$$

For seller

$$\begin{cases} \pi_{21}^1 = \pi_{23}^1 = J_1\phi_1 m_1^2 - c(q_1^2) > 0 & (3.1.4) \\ \pi_{31}^1 = \pi_{32}^1 = J_1\phi_1 m_1^3 - c(q_1^3) > 0 & (3.1.5) \end{cases}$$

For investor

$$\big[(1-2\sigma)\phi_1 z_1\big](1+R_1) = (n_{12}+n_{13})\phi_1 m_1^1 + (n_{21}+n_{23})\phi_1 m_1^2 + (n_{31}+n_{32})\phi_1 m_1^3 \quad (3.1.6)$$

Money market

$$\begin{cases} \sigma(\phi_1 m_1^1 + \phi_1 m_1^2 + \phi_1 m_1^3) + (1-\sigma)\phi_1 z_1 + F_1 = \phi_1 M_1 & (3.1.7) \\ \sigma\phi_2 m_2^2 = \phi_2 M_2 & (3.1.8) \\ \sigma\phi_3 m_3^3 = \phi_3 M_3 & (3.1.9) \end{cases}$$

The incumbency advantage from proposition 1 still applies here: as long as individual sellers enjoy positive profit from international trade, they have no incentive to deviate from the existing equilibrium.

A.5.2 Dual dominance: PCP

Now consider the case of double international currencies where the international trade between country 1 and 2 is settled through PCP, while country 3 relies on other country's currency for settlement. To achieve consistency of decision, country 3 sellers choose country 1 currency to settle trade with country 2, which is the same as country 1 seller's choice. Apply a similar procedure to other seller's choice, and the payment pattern is shown in figure 9, with the following equilibrium condition. *For buyer*

$$\begin{cases} R_1 = p_{11}L(q_1^1) = (p_{21}+p_{23})L(q_1^2) = (p_{31}+p_{32})L(q_1^3) & (3.2.1) \\ R_2 = p_{22}L(q_2^2) = (p_{13}+p_{12})L(q_2^1) & (3.2.2) \\ R_3 = p_{33}L(q_3^3) & (3.2.3) \end{cases}$$

For seller

$$\begin{cases} \pi_{12}^2 = \pi_{13}^2 = J_2\phi_2 m_2^1 - c(q_2^1) > 0 & (3.2.4) \\ \pi_{21}^1 = \pi_{23}^1 = J_1\phi_1 m_1^2 - c(q_1^2) > 0 & (3.2.5) \\ \pi_{31}^1 = \pi_{32}^1 = J_1\phi_1 m_1^3 - c(q_1^3) > 0 & (3.2.6) \\ \pi_{21}^1 > \pi_{21}^2 \Rightarrow J_1\phi_2 m_2^1 - c(q_2^1) > J_2\phi_2 m_2^2 - c(q_2^2) & (3.2.7) \\ \pi_{12}^2 > \pi_{12}^1 \Rightarrow J_2\phi_2 m_2^1 - c(q_2^1) > J_1\phi_1 m_1^1 - c(q_1^1) & (3.2.8) \end{cases}$$

For investor

$$\begin{cases} \big[(1-2\sigma)\phi_1 z_1\big](1+R_1) = (n_{21}+n_{23})\phi_1 m_1^2 + (n_{31}+n_{32})\phi_1 m_1^3 & (3.2.9) \\ \big[(1-2\sigma)\phi_2 z_2\big](1+R_2) = (n_{12}+n_{13})\phi_2 m_2^1 & (3.2.10) \end{cases}$$

Money market

$$\begin{cases} \sigma(\phi_1 m_1^1 + \phi_1 m_1^2 + \phi_1 m_1^3) + (1-2\sigma)\phi_1 z_1 + F_1 = \phi_1 M_1 & (3.2.11) \\ \sigma(\phi_2 m_2^2 + \phi_2 m_2^1) + (1-2\sigma)\phi_2 z_2 + F_2 = \phi_2 M_2 & (3.2.12) \\ \sigma\phi_3 m_3^3 = \phi_3 M_3 & (3.2.13) \end{cases}$$

With double international currencies, the incumbency advantage in proposition 1 is no longer present. The existence of such equilibrium requires not only positive profit for sellers, but also the incentive-compatible condition in (3.2.7) and (3.2.8), otherwise deviation is justified.

A.5.3 Dual dominance: LCP

For another possibility of double international currency, assume the trade between country 1 and 2 to be settled through LCP. Figure 10 shows the payment system, and several equilibrium conditions follow. *For buyer*

$$\begin{cases} R_1 = (p_{11}+p_{12}+p_{13})L(q_1^1) = (p_{31}+p_{32})L(q_1^3) & (3.3.1) \\ R_2 = (p_{22}+p_{21}+p_{23})L(q_2^2) & (3.3.2) \\ R_3 = p_{33}L(q_3^3) & (3.3.3) \end{cases}$$

For seller

$$\begin{cases} \pi_{12}^1 = \pi_{13}^1 = J_1\phi_1 m_1^1 - c(q_1^1) > 0 & (3.3.4) \\ \pi_{21}^2 = \pi_{23}^2 = J_2\phi_2 m_2^2 - c(q_2^2) > 0 & (3.3.5) \\ \pi_{31}^1 = \pi_{32}^1 = J_1\phi_1 m_1^3 - c(q_1^3) > 0 & (3.3.6) \end{cases}$$

For investor

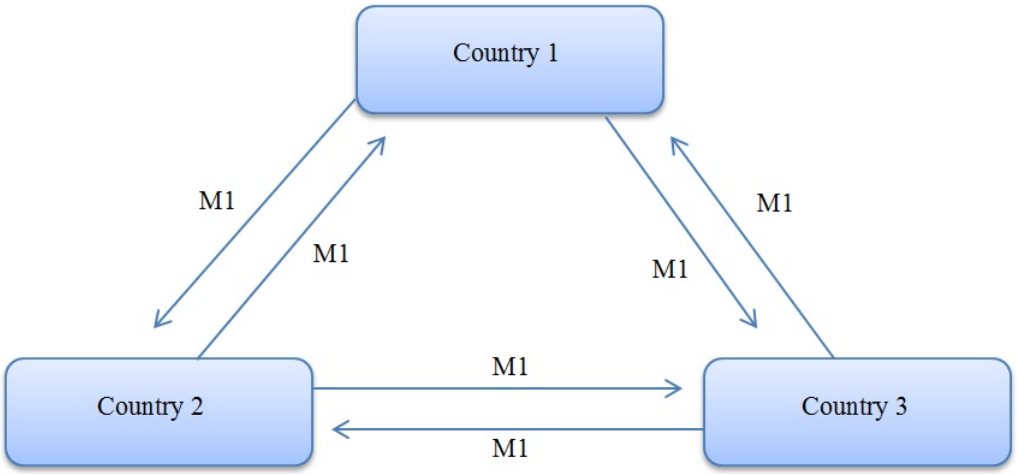
$$\begin{cases} \big[(1-2\sigma)\phi_1 z_1\big](1+R_1) = (n_{12}+n_{13})\phi_1 m_1^2 + (n_{31}+n_{32})\phi_1 m_1^3 & (3.3.7) \\ \big[(1-2\sigma)\phi_2 z_2\big](1+R_2) = (n_{21}+n_{23})\phi_2 m_2^2 & (3.3.8) \end{cases}$$

Money market

$$\begin{cases} \sigma(\phi_1 m_1^1 + \phi_1 m_1^3) + (1-2\sigma)\phi_1 z_1 + F_1 = \phi_1 M_1 & (3.3.9) \\ \sigma\phi_2 m_2^2 + (1-2\sigma)\phi_2 z_2 + F_2 = \phi_2 M_2 & (3.3.10) \\ \sigma\phi_3 m_3^3 = \phi_3 M_3 & (3.3.13) \end{cases}$$

One interesting feature in this system is the pattern of IVC. For PCP in figure 9, the trade between country 2 and 3 is completely settled by country 1 currency, while for LCP in figure 10, there's no such dominant IVC.

Figure 8: Three-country model: single international currency



A.6 Letter of credit step by step

Figure 1 shows the working mechanism of LC. The following step of LC is in order.

Step 1 Exporter and importer determine terms of trade and sign business contract.

Step 2 Importer would go to issuing bank, show the contract, and apply for LC. The issuing bank usually asks for a certain amount of collateral from importer before LC is issued.

Letter of credit is "a commitment by a bank on behalf of the buyer that payment would be made to the beneficiary provided that the terms and conditions stated in

Figure 9: Three-country model: dual international currency, PCP

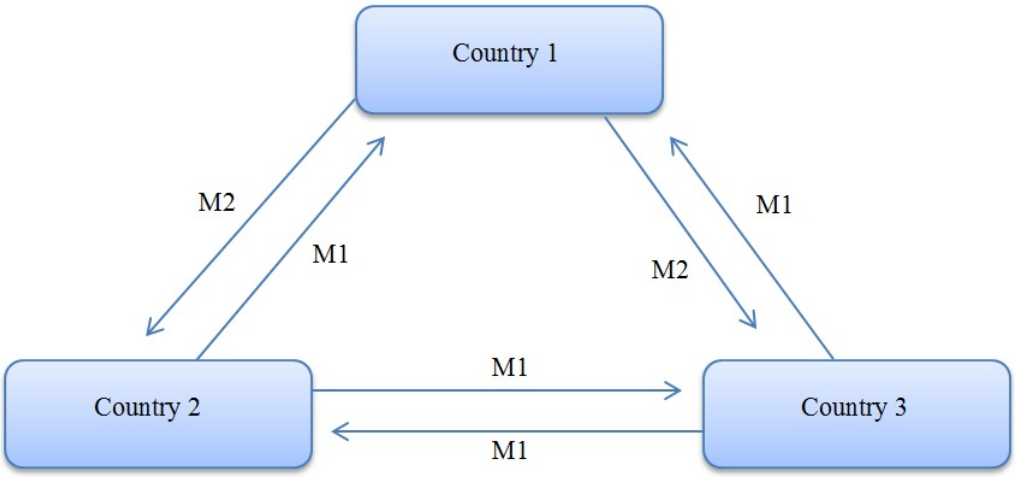
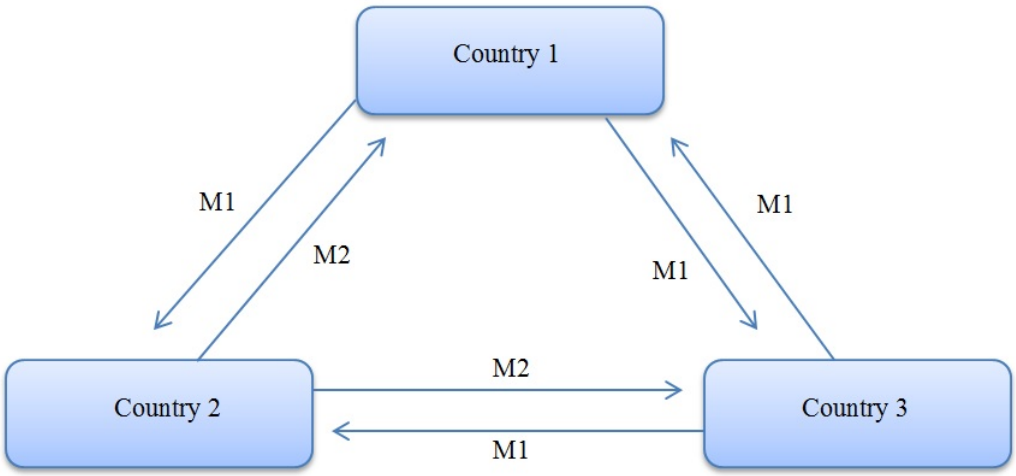


Figure 10: Three-country model: dual international currency, LCP



LC has been met, consisting of the presentation of specified documents" (US department of commerce). The issuing bank would make payment only a certain days after shipment, and that's the maturity of LC, usually around 3 months.

Step 3 The issuing bank would send LC to advising bank for scrutiny.

Step 4 After checking details, advising bank would notify exporter so that he could prepare shipment.

Step 5 Exporter makes shipment and gets the required document, especially bill of lading (B/L).

Bill of lading is a document issued by carrier which details a shipment of merchandise and gives title of that shipment to a specified party, usually its holder.

Step 6 Exporter sends required document to advising bank for payment.

Step 7 After checking the required document, advising bank would notify the issuing bank. In principle, exporter needs to wait until maturity of LC, but he is usually in urgent need of liquidity, so advising bank would make payment to exporter at discount.

Step 8 The principle of "borrow short and lend long" makes advising bank unwilling to hold LC, given its short maturity. Advising bank would sell combine LC and other required documents as trade acceptance and sell it to any interested parties.

The set of documents including LC and B/L is referred to as trade acceptance or banker's acceptance, whose payment is guaranteed by both issuing bank and advising bank, making it attractive for short-term investment.

Step 9 Upon maturity, anyone holding trade acceptance could go to issuing bank for payment. After checking the required document, issuing bank would notify importer. The importer then makes payment and gets shipment.

A.7 Data source and description

Table 6: Country list in panel regression

Country name	ISO 3-letter code	Sample period
Albania	ALB	2011, 2012, 2013
Algeria	DZA	2011, 2012, 2013
Argentina	ARG	2011
Armenia	ARM	2011, 2012, 2013
Austria	AUT	2011, 2012, 2013
Azerbaijan	AZE	2011, 2012, 2013

continued on next page

Country name	ISO 3-letter code	Sample period
Bangladesh	BGD	2011
Belarus	BLR	2011, 2012, 2013
Belgium	BEL	2011, 2012, 2013
Benin	BEN	2011, 2012, 2013
Bolivia	BOL	2011
Brazil	BRA	2011, 2012, 2013
Bulgaria	BGR	2011, 2012, 2013
Burkina Faso	BFA	2011, 2013
Cabo Verde	CPV	2011, 2012, 2013
Cambodia	KHM	2011, 2012, 2013
Cameroon	CMR	2011, 2012
Chile	CHL	2011, 2012, 2013
China, Hong Kong	HKG	2011, 2012, 2013
China, Macao	MAC	2011, 2012
China, mainland	CHN	2011, 2012, 2013
Colombia	COL	2011, 2012, 2013
Republic of Congo	COG	2012, 2013
Costa Rica	CRI	2011, 2012, 2013
Croatia	HRV	2011, 2012, 2013
Cyprus	CYP	2011, 2012
Czech Republic	CZE	2011, 2012, 2013
Denmark	DNK	2011, 2012, 2013
Dominican Republic	DOM	2011, 2012, 2013
Egypt	EGY	2011, 2012, 2013
Estonia	EST	2011, 2012, 2013
Fiji	FJI	2011, 2012, 2013
Finland	FIN	2011, 2012, 2013
France	FRA	2011, 2012, 2013
Gambia	GMB	2011, 2012, 2013
Georgia	GEO	2011
Germany	DEU	2011, 2012, 2013
Ghana	GHA	2011
Greece	GRC	2011, 2012
Guatemala	GTM	2011, 2012, 2013
Guyana	GUY	2011, 2012, 2013
Honduras	HND	2011, 2012
Hungary	HUN	2011, 2012, 2013
Iceland	ISL	2011, 2012, 2013

continued on next page

Country name	ISO 3-letter code	Sample period
India	IND	2011, 2012, 2013
Indonesia	IDN	2011, 2012, 2013
Iran	IRN	2011
Ireland	IRL	2011, 2012, 2013
Israel	ISR	2011
Italy	ITA	2011, 2012, 2013
Japan	JPN	2013
Kazakhstan	KAZ	2011, 2012, 2013
Kenya	KEN	2013
Republic of Korea	KOR	2011, 2012, 2013
Latvia	LVA	2011, 2012
Lithuania	LTU	2011, 2012, 2013
Macedonia	MKD	2011, 2012, 2013
Madagascar	MDG	2011, 2012, 2013
Malawi	MWI	2013
Malaysia	MYS	2011, 2012, 2013
Maldives	MDV	2011, 2012, 2013
Mali	MLI	2011, 2012
Malta	MLT	2011, 2012, 2013
Mauritania	MRT	2011, 2012
Mauritius	MUS	2011, 2012, 2013
Mexico	MEX	2011, 2012, 2013
Moldova	MDA	2011, 2013
Mongolia	MNG	2013
Morocco	MAR	2011, 2012, 2013
Mozambique	MOZ	2011, 2012, 2013
Nepal	NPL	2011, 2012, 2013
Netherlands	NLD	2011, 2012, 2013
Nicaragua	NIC	2011, 2012, 2013
Niger	NER	2011, 2012, 2013
Nigeria	NGA	2011, 2012, 2013
Pakistan	PAK	2011, 2012, 2013
Paraguay	PRY	2011, 2012, 2013
Peru	PER	2011, 2012, 2013
Philippines	PHL	2011, 2012, 2013
Poland	POL	2011, 2012, 2013
Portugal	PRT	2011, 2012, 2013
Romania	ROU	2011, 2012, 2013

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Country name	ISO 3-letter code	Sample period
Russia	RUS	2011, 2012, 2013
Sao Tome and Principe	STP	2011, 2012
Senegal	SEN	2011, 2012, 2013
Singapore	SGP	2011, 2012, 2013
Slovenia	SVN	2011, 2012, 2013
Solomon Islands	SLB	2011, 2012, 2013
South Africa	ZAF	2011, 2012, 2013
Spain	ESP	2011, 2012, 2013
Sri Lanka	LKA	2011, 2012, 2013
Sudan	SDN	2011
Sweden	SWE	2011, 2012
Switzerland	CHE	2011
Tanzania	TZA	2011, 2012, 2013
Thailand	THA	2011, 2012, 2013
Togo	TGO	2011, 2012, 2013
Tunisia	TUN	2011, 2012, 2013
Turkey	TUR	2011, 2012, 2013
Uganda	UGA	2011, 2012, 2013
United Kingdom	GBR	2011, 2012, 2013
Uruguay	URY	2011, 2012, 2013
Vietnam	VNM	2011, 2013
Yemen	YEM	2012
Zambia	ZMB	2011, 2012, 2013

Table 7: Independent variables in panel regression

Name	Description	Source
Market share	the share of country i's export in country j's total import	UN Comtrade database
Inflation differential	inflation difference between exporter and importer country Inflation measured by YoY change of CPI	IMF
Inflation volatility	coefficient of variation for monthly inflation, difference between exporter and importer	IMF
Exchange rate	average log change of bilateral nominal exchange rate within a year Nominal exchange rate is exporter currency per importer currency	IMF
Exchange rate volatility	coefficient of variation for monthly exchange rate within a year	IMF
Private credit / GDP	financial resources channeled to private sector by financial intermediary, scaled by GDP log difference between exporter and importer	World Bank
Capital account liberalization	Chinn-Ito index, de jure measure of capital account openness log difference between exporter and importer	Chinn and Ito (2006)
Distance	the great circle distance between capital cities, in kilometers, in log	Kristian Skrede Gleditsch Google map
Product differentiation	the share of differentiated goods in trade flow, in log	UN Comtrade Database Rauch (1999)
GDP	log difference of real GDP between exporter and importer country	World Bank
GDP per capita	log difference of real GDP per capita between exporter and importer country	World Bank
Border	equal to 1 if exporter and importer share border	Andrew Rose dataset
Former colonial relationship	equal to 1 if exporter and importer has former colonial relationship	Andrew Rose dataset
Common language	equal to 1 if exporter and importer share language	Andrew Rose dataset
Peg to USD	equal to 1 if country's home currency is pegged to USD	IMF

Notes: Bilateral nominal exchange rate calculated from each currency's nominal exchange rate against USD. For product differentiation, the goods with standard exchange or reference price is regarded as homogeneous, and the conservative category is adopted. The Chinn-Ito index is normalized between 0 and 1.

A.8 Robustness test of panel regression

To test the robustness of empirical finding in table 3, I did the following to verify the importance of financial development.

- Sub-sample test for different message types in SWIFT dataset (table 8 and 9)
- Determinants of VCP (table 10)
- Panel Heckit estimation (table 11, 12, 13)
- Use count share to get rid of valuation effect (table 14)
- Add fixed effect for year and destination region (table 15)
- Additional control variable (table 16)
- Different trade partners (table 17)

In sum, financial development is mostly significant with the expected sign.

Table 8: Determinants of currency use in trade, MT700

	PCP			LCP		
	Total	OECD	Non-OECD	Total	OECD	Non-OECD
Market share	0.60*	1.97***	1.35***	-0.06	-1.64	0.36
	(0.33)	(0.59)	(0.24)	(0.35)	(1.55)	(0.37)
Inflation	-0.00	0.00	-0.00	-0.00**	0.04**	-0.00*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.02)	(0.00)
Inflation volatility	-0.00	-0.00	-0.02	0.00	0.03	0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.03)	(0.01)
Exchange rate	-0.09***	-0.10***	-0.03***	0.07***	0.15***	0.04***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.03)	(0.01)
Exchange rate volatility	0.01	-0.02	-0.01	-0.01	0.00	-0.02*
	(0.01)	(0.01)	(0.01)	(0.01)	(0.03)	(0.01)
Private credit over GDP	0.09***	0.09***	0.10***	-0.11***	-0.42***	-0.06**
	(0.02)	(0.03)	(0.03)	(0.02)	(0.11)	(0.03)
Capital account liberalization	0.24***	0.12***	0.02	-0.13***	-0.22**	-0.14***
	(0.02)	(0.03)	(0.02)	(0.02)	(0.09)	(0.02)
Distance	-0.17***	-0.10***	-0.09***	-0.24***	-0.31***	-0.17***
	(0.02)	(0.03)	(0.02)	(0.02)	(0.07)	(0.03)
Product differentiation	0.59***	0.27**	0.38***	0.47***	0.47**	0.38***
	(0.07)	(0.11)	(0.09)	(0.07)	(0.23)	(0.08)
GDP	0.06***	0.01	-0.03***	-0.03***	-0.03	-0.04***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.03)	(0.01)
N	7,523	3,046	4,477	7,377	3,071	4,306
N (uncensored)	1375	1152	223	674	211	463

Note: Dependent variable is the value share of PCP in column (1)-(3), and the share of LCP in column (4)-(6), calculated from MT700 message in SWIFT dataset. Sample covers only cross-border trade. US not included. The trade within Euro zone not included. The trade among mainland China, Hong Kong, and Taiwan treated as cross-border. Data frequency is annual from 2011 to 2013. Econometric method is random-effect panel Tobit, since SWIFT dataset is restricted for confidentiality purpose: if the monthly transaction number for a country pair is less than or equal to 4, it's recorded as 0. Column (2) and (5) covers the subsample when exporter is OECD country, whereas column (3) and (6) for non-OECD exporter.

Table 9: Determinants of currency use in trade, MT400

	PCP			LCP		
	Total	OECD	Non-OECD	Total	OECD	Non-OECD
Market share	0.87**	4.25***	0.82***	0.75*	0.82	1.25**
	(0.43)	(0.78)	(0.26)	(0.41)	(0.80)	(0.58)
Inflation	-0.00	0.01	-0.00	0.00	0.01	0.01*
	(0.00)	(0.01)	(0.00)	(0.00)	(0.01)	(0.00)
Inflation volatility	-0.00	-0.00	0.00	0.01	0.00	0.02
	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)
Exchange rate	-0.06***	-0.07***	0.01	0.09***	0.11***	0.08***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Exchange rate volatility	0.01	-0.01	-0.01	-0.01	0.00	-0.04***
	(0.01)	(0.02)	(0.01)	(0.01)	(0.02)	(0.01)
Private credit over GDP	0.08***	0.02	0.14***	-0.13***	-0.28***	-0.10***
	(0.03)	(0.04)	(0.03)	(0.02)	(0.05)	(0.03)
Capital account liberalization	0.21***	0.17***	0.01	-0.17***	-0.31***	-0.24***
	(0.02)	(0.03)	(0.02)	(0.02)	(0.05)	(0.03)
Distance	-0.25***	-0.21***	-0.11***	-0.30***	-0.22***	-0.29***
	(0.03)	(0.04)	(0.02)	(0.03)	(0.04)	(0.04)
Product differentiation	0.66***	0.18	0.39***	0.34***	0.45***	0.22**
	(0.11)	(0.15)	(0.10)	(0.07)	(0.13)	(0.09)
GDP	0.07***	0.05***	-0.02**	-0.07***	-0.08***	-0.10***
	(0.01)	(0.02)	(0.01)	(0.01)	(0.02)	(0.01)
N	5,532	2,396	3,136	5,615	2,518	3,097
N (uncensored)	856	698	158	988	353	635

Note: Dependent variable is the value share of PCP in column (1)-(3), and the share of LCP in column (4)-(6), calculated from MT400 message in SWIFT dataset. Sample covers only cross-border trade. US not included. The trade within Euro zone not included. The trade among mainland China, Hong Kong, and Taiwan treated as cross-border. Data frequency is annual from 2011 to 2013. Econometric method is random-effect panel Tobit, since SWIFT dataset is restricted for confidentiality purpose: if the monthly transaction number for a country pair is less than or equal to 4, it's recorded as 0. Column (2) and (5) covers the subsample when exporter is OECD country, whereas column (3) and (6) for non-OECD exporter.

Table 10: Determinants of vehicle currency use in trade, 2011-2013

	Total	OECD	Non-OECD
Market share	0.88**	0.37	-1.46**
	(0.43)	(0.57)	(0.65)
Inflation	-0.00	-0.00	-0.00
	(0.00)	(0.00)	(0.00)
Inflation volatility	-0.03***	-0.01	-0.05***
	(0.01)	(0.01)	(0.02)
Exchange rate	0.04***	0.06***	-0.01
	(0.01)	(0.01)	(0.01)
Exchange rate volatility	0.01	0.02	0.04**
	(0.01)	(0.01)	(0.02)
Private credit over GDP	0.14***	0.02	0.24***
	(0.03)	(0.03)	(0.04)
Capital account liberalization	-0.01	0.08***	0.14***
	(0.02)	(0.03)	(0.03)
Distance	0.30***	0.19***	0.39***
	(0.03)	(0.03)	(0.05)
Product differentiation	-0.14**	-0.28***	0.04
	(0.07)	(0.10)	(0.11)
GDP	0.09***	0.01	0.26***
	(0.01)	(0.01)	(0.02)
N	8,484	3,449	5,035
N (uncensored)	2671	1567	1104

Note: US not included in sample. Data frequency is annual. Dependent variable is the share of VCP. Econometric method is panel Tobit, since SWIFT dataset is restricted for confidentiality purpose: if the monthly transaction number for a country pair is less than or equal to 4, it's recorded as 0. Column (2) covers subsample when exporter is OECD country, and column (3) for non-OECD exporter.

Table 11: Determinants of PCP, panel Heckit

	Total		OECD		Non-OECD	
	Selection	Intensity	Selection	Intensity	Selection	Intensity
Market share	15.16***	-0.46***	51.01***	0.02	11.75***	0.49
	(3.28)	(0.17)	(6.53)	(0.27)	(1.65)	(0.31)
Inflation	-0.00	-0.00	0.01	0.00	-0.00	-0.01***
	(0.02)	(0.00)	(0.02)	(0.00)	(0.01)	(0.00)
Inflation volatility	-0.09	-0.00	-0.15*	-0.00	-0.02	-0.02*
	(0.07)	(0.00)	(0.08)	(0.01)	(0.09)	(0.01)
Exchange rate	-0.65***	-0.03***	-0.60***	-0.03***	-0.10**	0.00
	(0.06)	(0.01)	(0.05)	(0.01)	(0.04)	(0.01)
Exchange rate volatility	0.09	-0.01	0.05	-0.02***	-0.20***	0.00
	(0.07)	(0.01)	(0.10)	(0.01)	(0.07)	(0.01)
Private credit over GDP	0.75***	0.00	0.37**	0.01	0.79***	0.11***
	(0.18)	(0.02)	(0.19)	(0.02)	(0.17)	(0.04)
Capital account liberalization	2.30***	0.07***	1.60***	0.02	-0.09	0.06***
	(0.18)	(0.02)	(0.19)	(0.02)	(0.12)	(0.02)
Distance	-1.44***	-0.10***	-0.24	-0.09***	-0.60***	-0.08**
	(0.22)	(0.02)	(0.18)	(0.02)	(0.15)	(0.03)
Product differentiation	5.72***	0.19***	1.89***	0.22***	3.35***	0.13
	(0.60)	(0.07)	(0.72)	(0.07)	(0.75)	(0.12)
GDP	0.31***	0.03***	-0.30***	0.01*	-0.22***	-0.01
	(0.08)	(0.01)	(0.08)	(0.01)	(0.06)	(0.01)
Inverse Mills ratio		0.02*		0.03		0.07**
		(0.01)		(0.02)		(0.04)
Observations	8,373	1,985	3,355	1,696	5,018	326

Note: The first part model is panel Probit with random effect, while the second part is panel random-effect regression, adding inverse Mills ratio as correction. The dependent variable in first part is a dummy variable for producer currency settlement: equal to 1 when exporter's home currency is used, otherwise equal to zero. The second part is panel random-effect regression for the subsample when exporter's home currency is used. The dependent variable is the value share of producer currency settlement.

Table 12: Determinants of LCP, panel Heckit

	Total		OECD		Non-OECD	
	Selection	Intensity	Selection	Intensity	Selection	Intensity
Market share	4.99**	-0.62**	17.07***	-1.71***	4.55***	0.82
	(2.37)	(0.31)	(4.37)	(0.62)	(1.68)	(0.75)
Inflation	-0.02*	0.00	0.16**	0.01	-0.02	-0.00
	(0.01)	(0.00)	(0.07)	(0.01)	(0.01)	(0.00)
Inflation volatility	-0.04	0.01	-0.01	-0.01	-0.01	0.01*
	(0.06)	(0.01)	(0.15)	(0.01)	(0.07)	(0.01)
Exchange rate	0.41***	0.02	0.87***	0.05***	0.26***	0.08*
	(0.04)	(0.02)	(0.07)	(0.01)	(0.04)	(0.04)
Exchange rate volatility	-0.13**	0.01	-0.34**	-0.00	-0.20***	-0.04
	(0.06)	(0.01)	(0.16)	(0.01)	(0.06)	(0.03)
Private credit over GDP	-0.57***	-0.05*	-2.27***	-0.15***	-0.29***	-0.10**
	(0.14)	(0.03)	(0.32)	(0.04)	(0.11)	(0.05)
Capital account liberalization	-1.22***	-0.03	-2.15***	-0.09	-1.26***	-0.36*
	(0.14)	(0.05)	(0.30)	(0.05)	(0.14)	(0.20)
Distance	-1.22***	-0.18***	-1.06***	-0.15***	-0.70***	-0.37***
	(0.15)	(0.05)	(0.22)	(0.03)	(0.12)	(0.11)
Product differentiation	2.63***	-0.09	3.33***	0.12	1.42***	0.18
	(0.42)	(0.11)	(0.95)	(0.10)	(0.32)	(0.22)
GDP	-0.31***	-0.03*	-0.70***	-0.01	-0.32***	-0.12**
	(0.06)	(0.01)	(0.12)	(0.01)	(0.05)	(0.05)
Inverse Mills ratio		0.01		0.02		0.28*
		(0.05)		(0.02)		(0.17)
Observations	8,319	1,506	3,429	493	4,890	998

Note: The first part model is panel Probit with random effect, while the second part is panel random-effect regression, adding inverse Mills ratio as correction. The dependent variable in first part is a dummy variable for local currency settlement: equal to 1 when importer's home currency is used, otherwise equal to zero. The second part is panel random-effect regression for the subsample when importer's home currency is used. The dependent variable is the value share of local currency settlement.

Table 13: Determinants of VCP, panel Heckit

	Total		OECD		Non-OECD	
	Selection	Intensity	Selection	Intensity	Selection	Intensity
Market share	8.36***	-0.20**	11.46***	-1.38***	0.71	-0.17***
	(1.84)	(0.08)	(2.93)	(0.21)	(2.87)	(0.06)
Inflation	-0.01	0.00	-0.00	0.00	-0.03	0.00*
	(0.01)	(0.00)	(0.01)	(0.00)	(0.02)	(0.00)
Inflation volatility	-0.07	-0.00	0.03	0.00	-0.13	-0.00*
	(0.05)	(0.00)	(0.07)	(0.00)	(0.12)	(0.00)
Exchange rate	0.05**	0.00***	0.22***	0.01***	-0.30***	-0.00***
	(0.02)	(0.00)	(0.04)	(0.00)	(0.08)	(0.00)
Exchange rate volatility	0.10**	-0.00	0.17**	0.01**	0.26**	-0.00
	(0.05)	(0.00)	(0.09)	(0.00)	(0.11)	(0.00)
Private credit over GDP	0.22***	0.01***	-0.01	0.02*	0.93***	0.01*
	(0.08)	(0.01)	(0.14)	(0.01)	(0.25)	(0.00)
Capital account liberalization	0.17**	-0.02***	0.45***	-0.00	1.32***	0.01***
	(0.07)	(0.00)	(0.14)	(0.01)	(0.29)	(0.00)
Distance	1.41***	0.05***	1.44***	0.04***	3.40***	0.02***
	(0.09)	(0.01)	(0.13)	(0.01)	(0.33)	(0.00)
Product differentiation	0.18	-0.09***	0.08	-0.12***	0.69	-0.04***
	(0.26)	(0.01)	(0.61)	(0.03)	(0.64)	(0.01)
GDP	0.06*	0.00*	-0.23***	0.02***	1.10***	0.01***
	(0.03)	(0.00)	(0.06)	(0.00)	(0.12)	(0.00)
Inverse Mills ratio		0.22***		0.72***		-0.03***
		(0.08)		(0.21)		(0.01)
Observations	7,242	5,926	3,213	2,516	4,029	3,410

Note: The first part model is panel Probit with random effect, while the second part is panel random-effect regression, adding inverse Mills ratio as correction. The dependent variable in first part is a dummy variable for vehicle currency settlement: equal to 1 when vehicle currency is used, otherwise equal to zero. The second part is panel random-effect regression for the subsample when vehicle currency is used. The dependent variable is the value share of vehicle currency settlement.

Table 14: Determinants of currency use in trade, count share

	PCP			LCP		
	Total	OECD	Non-OECD	Total	OECD	Non-OECD
Market share	0.37*	1.64***	1.29***	0.46*	0.98*	0.60*
	(0.22)	(0.49)	(0.20)	(0.25)	(0.54)	(0.36)
Inflation	-0.00	-0.00	-0.00	-0.00	0.01*	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)
Inflation volatility	-0.01	-0.01**	-0.00	0.01*	-0.01	0.02**
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Exchange rate	-0.07***	-0.09***	-0.02***	0.07***	0.09***	0.06***
	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Exchange rate volatility	0.00	-0.01	-0.01	-0.01	-0.01	-0.02**
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Private credit over GDP	0.10***	0.07***	0.13***	-0.11***	-0.30***	-0.07***
	(0.01)	(0.02)	(0.02)	(0.02)	(0.03)	(0.02)
Capital account liberalization	0.16***	0.09***	0.01	-0.15***	-0.20***	-0.22***
	(0.01)	(0.02)	(0.01)	(0.01)	(0.03)	(0.02)
Distance	-0.19***	-0.17***	-0.08***	-0.25***	-0.16***	-0.24***
	(0.01)	(0.03)	(0.02)	(0.02)	(0.02)	(0.03)
Product differentiation	0.39***	0.11	0.28***	0.17***	0.33***	0.09*
	(0.05)	(0.08)	(0.06)	(0.04)	(0.09)	(0.05)
GDP	0.04***	0.00	-0.04***	-0.05***	-0.06***	-0.08***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
N	8,412	3,384	5,028	8,373	3,440	4,933
N (uncensored)	1735	1389	346	1392	465	927

Note: Dependent variable is the count share of PCP in column (1)-(3), and the share of LCP in column (4)-(6), calculated SWIFT dataset. Sample covers only cross-border trade. US not included. The trade within Euro zone not included. The trade among mainland China, Hong Kong, and Taiwan treated as cross-border. Data frequency is annual from 2011 to 2013. Econometric method is random-effect panel Tobit, since SWIFT dataset is restricted for confidentiality purpose: if the monthly transaction number for a country pair is less than or equal to 4, it's recorded as 0. Column (2) and (5) covers the subsample when exporter is OECD country, whereas column (3) and (6) for non-OECD exporter.

Table 15: Determinants of currency use in trade, adding fixed effect

	PCP			LCP		
	Total	OECD	Non-OECD	Total	OECD	Non-OECD
Market share	0.93***	2.29***	1.31***	0.46	0.79	0.69
	(0.29)	(0.53)	(0.22)	(0.32)	(0.80)	(0.47)
Inflation	-0.00	0.00	-0.00	-0.00**	0.01	-0.00*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)
Inflation volatility	-0.01	-0.01	-0.01	0.01	-0.01	0.02
	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)
Exchange rate	-0.09***	-0.09***	-0.02***	0.03***	0.06***	0.03***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Exchange rate volatility	0.01	-0.01	-0.01	0.01	-0.02	0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)
Private credit over GDP	0.13***	0.06*	0.18***	-0.02	-0.18***	0.03
	(0.02)	(0.03)	(0.03)	(0.02)	(0.04)	(0.03)
Capital account liberalization	0.22***	0.10***	0.02	-0.05**	-0.15***	-0.08***
	(0.02)	(0.03)	(0.02)	(0.02)	(0.04)	(0.03)
Distance	-0.11***	-0.04	-0.09***	-0.20***	-0.08**	-0.31***
	(0.02)	(0.04)	(0.02)	(0.02)	(0.04)	(0.04)
Product differentiation	0.58***	0.32***	0.37***	0.17***	0.40***	0.06
	(0.07)	(0.10)	(0.08)	(0.06)	(0.13)	(0.08)
GDP	0.05***	-0.02*	-0.02**	-0.01	-0.03**	-0.02
	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)
N	8,373	3,355	5,018	8,319	3,429	4,890
N (uncensored)	1,584	1,282	302	1,158	409	749
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Region FE	Yes	Yes	Yes	Yes	Yes	Yes

Note: Dependent variable is the value share of PCP in column (1)-(3), and the share of LCP in column (4)-(6), calculated from MT700 and MT400 message in SWIFT dataset. Sample covers only cross-border trade. US not included. The trade within Euro zone not included. The trade among mainland China, Hong Kong, and Taiwan treated as cross-border. Data frequency is annual from 2011 to 2013. Econometric method is random-effect panel Tobit, since SWIFT dataset is restricted for confidentiality purpose: if the monthly transaction number for a country pair is less than or equal to 4, it's recorded as 0. Column (2) and (5) covers the subsample when exporter is OECD country, whereas column (3) and (6) for non-OECD exporter. Constant and Fixed effect for year and destination region are omitted.

Table 16: Determinants of currency use in trade, additional control

	PCP			LCP		
	Total	OECD	Non-OECD	Total	OECD	Non-OECD
Market share	1.18***	2.03***	1.70***	-0.03	0.37	0.09
	(0.33)	(0.55)	(0.28)	(0.45)	(0.88)	(0.63)
Inflation	-0.00	0.00	-0.00	-0.00**	0.01	-0.01**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)
Inflation volatility	-0.01	-0.01	-0.01	0.00	-0.01	0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)
Exchange rate	-0.08***	-0.10***	-0.03***	0.05***	0.08***	0.03***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Exchange rate volatility	-0.00	-0.02*	-0.01	0.00	-0.02	0.00
	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)
Private credit over GDP	0.17***	0.14***	0.18***	-0.06**	-0.23***	0.01
	(0.02)	(0.03)	(0.03)	(0.03)	(0.05)	(0.04)
Capital account liberalization	0.26***	0.17***	0.04	-0.11***	-0.19***	-0.12***
	(0.02)	(0.03)	(0.02)	(0.02)	(0.05)	(0.03)
Distance	-0.13***	-0.05	-0.10***	-0.21***	-0.11**	-0.32***
	(0.02)	(0.04)	(0.02)	(0.03)	(0.04)	(0.05)
Product differentiation	0.61***	0.30***	0.35***	0.18***	0.47***	0.03
	(0.07)	(0.10)	(0.08)	(0.06)	(0.14)	(0.08)
GDP	0.04***	-0.00	-0.02**	-0.02**	-0.04***	-0.02
	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)
Border	-0.20**	0.03	-0.05	-0.07	-0.19	-0.00
	(0.10)	(0.14)	(0.09)	(0.10)	(0.15)	(0.14)
Former colonial relationship	0.35***	0.19*	0.10	0.45***	0.51***	0.44***
	(0.09)	(0.11)	(0.10)	(0.09)	(0.14)	(0.13)
Common language	-0.20***	-0.31***	0.16***	-0.04	-0.00	0.02
	(0.05)	(0.08)	(0.05)	(0.06)	(0.10)	(0.08)
GDP per capita	-0.08***	-0.18***	-0.02	0.12***	0.11**	0.08**
	(0.03)	(0.03)	(0.03)	(0.03)	(0.06)	(0.04)
Peg to USD (i)	-0.37***	.	0.04	0.16	.	0.29*
	(0.10)	.	(0.08)	(0.12)	.	(0.15)
Peg to USD (j)	0.41***	0.29*	-0.06	0.28**	0.12	0.45**
	(0.12)	(0.16)	(0.20)	(0.11)	(0.15)	(0.19)
N	7,942	3,237	4,705	7,890	3,309	4,581
N (uncensored)	1,546	1,250	296	1,120	401	719
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Region FE	Yes	Yes	Yes	Yes	Yes	Yes

Note: Dependent variable is the value share of PCP in column (1)-(3), and the share of LCP in column (4)-(6), calculated from MT700 and MT400 message in SWIFT dataset. Sample covers only cross-border trade. US not included. The trade within Euro zone not included. The trade among mainland China, Hong Kong, and Taiwan treated as cross-border. Data frequency is annual from 2011 to 2013. Econometric method is random-effect panel Tobit, since SWIFT dataset is restricted for confidentiality purpose: if the monthly transaction number for a country pair is less than or equal to 4, it's recorded as 0. Column (2) and (5) covers the subsample when exporter is OECD country, whereas column (3) and (6) for non-OECD exporter. Constant and Fixed effect for year and destination region are omitted. Peg to USD (i) is equal to 1 if exporter's home currency is pegged to USD. Peg to USD (j) is equal to 1 if importer's home currency is pegged to USD.

Table 17: Determinants of currency use in trade, North and South

	PCP			LCP		
	North-North	South-South	North-South	North-North	South-South	North-South
Market share	3.26***	1.07***	1.94***	0.22	0.85*	1.25
	(0.99)	(0.26)	(0.57)	(0.99)	(0.44)	(0.87)
Inflation	-0.03*	-0.00	-0.00	0.03**	0.01**	-0.01***
	(0.02)	(0.00)	(0.00)	(0.02)	(0.00)	(0.00)
Inflation volatility	-0.01	0.00	-0.02**	0.02	-0.02	0.02
	(0.02)	(0.02)	(0.01)	(0.02)	(0.03)	(0.01)
Exchange rate	-0.09***	-0.03**	-0.07***	0.12***	0.03*	0.07***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Exchange rate volatility	-0.07**	-0.00	0.01	0.03	-0.02	-0.00
	(0.03)	(0.01)	(0.01)	(0.03)	(0.02)	(0.01)
Private credit over GDP	0.20***	0.12***	0.13***	-0.21***	-0.16***	-0.15***
	(0.06)	(0.03)	(0.03)	(0.06)	(0.05)	(0.03)
Capital account liberalization	0.27***	0.10***	0.18***	-0.24**	-0.03	-0.17***
	(0.10)	(0.03)	(0.02)	(0.10)	(0.04)	(0.03)
Distance	0.00	-0.16***	-0.16***	-0.18***	-0.27***	-0.20***
	(0.04)	(0.03)	(0.03)	(0.04)	(0.05)	(0.03)
Product differentiation	0.09	0.44***	0.47***	0.46***	0.40***	0.11
	(0.19)	(0.12)	(0.09)	(0.17)	(0.15)	(0.08)
GDP	-0.04*	0.00	0.04***	-0.06**	0.01	-0.06***
	(0.02)	(0.01)	(0.01)	(0.02)	(0.02)	(0.01)
N	912	2,775	4,686	932	2,777	4,610
N (uncensored)	299	190	1,095	304	112	3,629

Note: Dependent variable is the value share of PCP in column (1)-(3), and the share of LCP in column (4)-(6), calculated from MT700 and MT400 message in SWIFT dataset. Sample covers only cross-border trade. US not included. The trade within Euro zone not included. The trade among mainland China, Hong Kong, and Taiwan treated as cross-border. Data frequency is annual from 2011 to 2013. Econometric method is random-effect panel Tobit, since SWIFT dataset is restricted for confidentiality purpose: if the monthly transaction number for a country pair is less than or equal to 4, it's recorded as 0. Column (1) and (4) covers the subsample for the trade between OECD countries, column (2) and (5) for the trade between Non-OECD countries, and column (3) and (6) for the trade between OECD and Non-OECD countries. Constant omitted.