# Jumpstarting an International Currency*

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**Abstract**

Monetary and financial policies that lower the cost of credit for working capital in a currency outside of its country can provide the impetus for that currency to be used in international trade. This paper shows this in theory, by exploring the complementarity in the currency used for financing working capital and the currency used for invoicing sales. Financial policies by a central bank can jump-start the use of its currency outside a country's borders. In the data, the creation of 38 swap lines by the People's Bank of China between 2009 and 2018 provides a test of the theory. Signing a swap line with a country is significantly associated with increases in the use of the RMB in payments to and from that country in the following months.

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# 1 Introduction

An international currency is a monetary unit that is used significantly in cross-border transactions. The few currencies that qualify are the euro, the yen, pound sterling, the yuan and, of course, the US dollar, which dominates invoicing, issuance of financial assets, international reserves, and almost any measure of international use. A significant literature has studied the benefits for a country of its currency dominating, which include political power, seignorage revenues, safety premia in its financial assets, and favorable movements in exchange rates following shocks.[1] But before a currency can become dominant, it has to become international. Fewer studies have investigated how a currency achieves that status, and even fewer ask which government policies assist (or hinder) that jumpstart. This is the topic of this paper.

In 1912, the United States was the world's largest exporter, but the USD was not an international currency. US firms and banks used the London financial markets to access trade credit denominated in GBP. The Federal Reserve Act of 1913 deregulated the banking sector, allowing US banks to open branches abroad, and affirmed the pursuit of a stable exchange rate. The first president of the FRB New York, Benjamin Strong, had an explicit goal of making the USD an international currency and took many measures to create a liquid secondary market in New York for USD-denominated trade acceptances, credits that firms took to fund international trade. Particularly important was giving banks the ability to discount these acceptances at the Federal Reserve. The Fed became a lender of last resort to firms trading in USD, by being the backstop buyer of trade acceptances from their banks in the secondary market. By some estimates, between 1923 and 1929, the Fed owned as much as half of all issued trade acceptances as a result of this aggressive policy of discounting.[2] By 1925, the USD had become an international currency, and by World War II it had become the dominant currency. Did the policies of the Fed contribute to jumpstarting the USD as an international currency? Or was this an inevitable consequence of the increasing size of the US economy, or a response to the negative shock to the London market caused by war, with no role for policy?

Fast forward almost one century to China in 2009. It was about to become the largest goods exporter in the world, as well as the largest creditor, but strict capital controls made it almost impossible for the RMB to be used outside its borders. Starting in July of

[1]See Prasad (2015), Gopinath (2015), Eichengreen, Mehl and Chitu (2017), Ilzetzki, Reinhart and Rogoff (2020) among many others.

[2]See Eichengreen (2011).

2009, the Chinese government enacted a series of policies to internationalize the RMB. It started with a trade settlement pilot scheme, allowing for the settlement of trade claims from neighboring countries in RMB, and it continued by creating an offshore market in Hong Kong, which could lend RMB overseas. The People's Bank of China (PBoC) also started in 2009 signing swap lines with foreign central banks, effectively lending RMB to banks in those countries, with the credit risk and the monitoring being done by the foreign central bank, often with collateral tied to international trade credits. Taken as a whole, these policies bear striking resemblances to those pursued by the Fed almost a century earlier. The result was again the jumpstart of an international currency. By 2016, the IMF included the RMB in its SDR basket of international currencies with a weight of 10.9%. By the end of 2019, a decade after the start of the policies, the RMB accounted for 2.0% of foreign currency reserves starting from virtually zero in 2009.[3] Is it a coincidence that similar policies succeeded again? Or was it again a third factor, associated with the rise of the Chinese economy, that gave the RMB its international status, with little or no influence of these policies?

This paper answers these questions in two complementary ways. Theoretically, it proposes a small open economy model where firms choose the currency in which to obtain working capital and trade credit, as well as the currency they set the price for their sales in. Comparing a dominant international currency with a rising one, the model derives thresholds that a currency must clear before firms in other countries start using it for their credit and their sales. The thresholds depend on: the distribution of financing costs in the rising currency, the relative variances of bilateral exchange rates, and the covariance of domestic input costs with the rising currency exchange rate. If they are exceeded, then the currency can rise to international status. If so, there is a complementarity between the currency choices for credit and sales that creates a jumpstart. Central bank policies, like the lending programs and discount facilities adopted by the Fed in the 1910s and the PBoC in the 2010s, can trigger this process.

The second contribution of the paper is an empirical analysis of 38 PBoC swap lines signed between 2009 and 2018 providing RMB lending of last resort to foreign firms. These recent central bank policies are interesting in their own right, in light of their rapid growth. For our purposes, they have the benefit of being signed with different countries at different times creating some variation that we exploit to answer the questions raised

[3] See Prasad (2016), Eichengreen and Lombardi (2017) and IMF dataset on currency composition of official foreign exchange reserves.

above. We combine them with SWIFT data on payment settlements across borders at a monthly frequency, broken down by currency and usage, for the entire global network. The payments data clearly show the jumpstart of the RMB usage.

The empirical analysis compares countries that signed a RMB swap line with those that did not, around the same time. We control for a series of factors that could generate reverse causality, as well as use exogenous political variation and swap lines signed by neighboring countries to isolate the impact of the swap lines on RMB usage. Our baseline estimates suggest that a swap line raises the probability that the country uses the RMB for payments by approximately 20%. The effect appears to be permanent.

**Literature review:** Relative to the literature, Eichengreen, Mehl and Chitu (2017) is one of the few studies that asks whether central bank's policies can jumpstart the international use of a currency. In the context of the Fed, it has been difficult to separate the effect of the policies from other factors. We provide an analogy with the PBoC, and use its swap lines as a way to test for these effects. In the context of the PBoC, McDowell (2019) discusses the impact of its policies to internationalize the RMB. We contribute a model that highlights one way in which these policies work, and an empirical quantification of how much the policies have mattered. Bahaj and Reis (2018) study the USD swap lines established by the Federal Reserve. While similar in size to the ones established by the PBoC, as the total notional limit of approximately RMB 3tr is comparable to the USD 500bn of peak drawings from the Fed's swap line, their features and aims are quite different. The USD swaps: (i) had shorter maturities, (ii) involved only a handful of advanced economies as opposed to the large and diverse set of countries with RMB swap lines, (iii) were designed to address the dollar funding needs of foreign banks, as opposed to trade credit and working capital, (iv) put a ceiling on covered-interest parity deviations in active USD forward markets, while for many of the countries in our sample there is no active RMB forward market, and (v) were needed because of the USD's dominance, as opposed to the RMB swap lines that were deployed to start the internationalization of the RMB.[4]

A growing analytical literature asks why the USD became dominant, in terms of fundamentals and possibly multiple equilibrium, and further asks what are its consequences (Maggiori, 2017, Gourinchas, Rey and Sauzet, 2019, Gopinath et al., 2020, Chahrour and Valchev, 2020). We contribute to this literature by analysing the early stages of adoption,

[4]See, for instance, this article published by the PBoC describing the swap lines as a tool to encourage currency use (last accessed 16th April 2020).

when the currency went from zero to positive usage, well before it became dominant. Also, we focus on policies, especially those adopted by the central bank, that can affect the internationalization of the currency.

In terms of mechanisms, we model the effect of the choice of currency for pricing on the choice of currency for working capital credit. On the crucial role of working capital for international trade, see Amiti and Weinstein (2011). Closest to our paper is Bruno and Shin (2019) who also emphasize the importance of the currency of the credit that firms use for their working capital. Their focus, however, is on the implications of using the USD to denominate credit and on how changes in the exchange rate transmit to these costs of production. Likewise, Eren and Malamud (2019) propose that the dominance of the dollar arises from its role in denominating credit, and study the impact that US monetary policy has all over the world as a result. We study a different set of policies, a complementarity between the currency of pricing and that of credit, and a rising currency, the RMB, as opposed to the dominant one, the USD. Gopinath and Stein (2018) also study a complementarity between finance and invoicing for firms, but they focus on the problem of domestic banks, which want to give credit in a foreign currency to domestic firms in order to match the desired foreign currency deposits of domestic households.

Our model of choice of currency invoicing builds on the work of Engel (2006) and Gopinath, Itskhoki and Rigobon (2010) that emphasize a firm's desire to match the currency exposure of its marginal costs with that of its revenues separately in each of their markets. In our setup, because the currency of working capital affects the marginal costs of a firm across all its markets, a second new complementarity arises between the choices of pricing in each of the firm's markets. Much of the literature on currency invoicing, following Bacchetta and van Wincoop (2005), Goldberg and Tille (2008) has focused on a third complementarity, across firms in the same market, arising from the demand for goods. We incorporate this different channel in one of our extensions, and it does not change the main conclusions. Mukhin (2018) studies the general equilibrium of a world in which exporters and importers are all choosing their currencies of invoicing. Our analysis of a small open economy does not include these global interactions, but we conjecture that taking them into account would lead to similar insights.

Recent empirical work has used firm-level data on invoicing to characterize the firm-level determinants of invoicing choices (Goldberg and Tille, 2016, Corsetti, Crowley and Han, 2018, Chen, Chung and Novy, 2018, Amiti, Itskhohi and Konings, 2019), while other work looks at the denomination of financial assets (Maggiori, Neiman and Schreger, 2019). Our data is on payments, rather than invoicing, and it is at the country rather than firm-level, but it covers the whole world for a decade, as opposed to just one country for a shorter period of time.

Sections 2 to 4 contain the theory of the paper: the core model, its predictions for the role of the rising currency, and a series of extensions. Sections 5 and 6 contain the empirical analysis, describing the data and statistically isolating the role of policy. Section 7 concludes.

# 2 A model of currency choices

The model in this section captures in a simple setup the complementarity between a firm's currency choice for its sales, and the currency choice of its working capital credit. Section 4 relaxes some of its sharp assumptions.

## 2.1 The environment

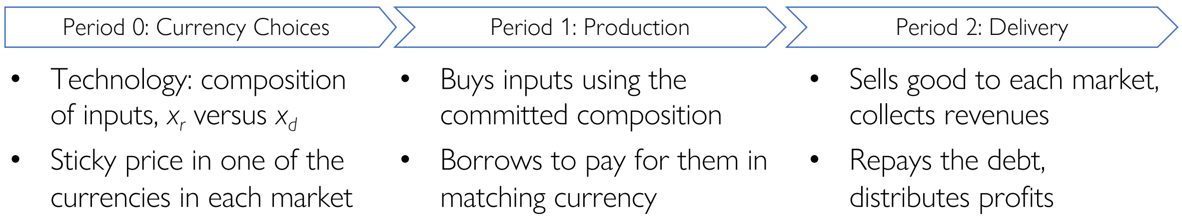
A small open economy has a continuum of firms indexed by $j \in [0,1]$. Each firm sells to a continuum of markets in the unit interval indexed by $i$, each having its own currency. Market 1 is the market of the current dominant currency, which we will distinguish by using the subscript $d$. Market 0 refers to the country of the rising international currency, which will carry the subscript $r$. These two markets have positive mass in the sales of each firm, reflecting the size of their economies, while $i \in (0,1)$ are small open economies each individually with a zero mass in firms' sales.

There are three periods, distinguishing between three stages of choices that each firm must make. Figure 1 displays these choices over time.

First, in period 0, the firm chooses the currency that will be used to price its goods in the future. Prices are nominally sticky, so that given different realizations of the nominal exchange rate in the future, the currency choice affects the actual demand and revenues of the firm. The firm can choose between the domestic currency, the currency of the market to which it is selling, the dominant currency $d$, or the rising international currency $r$.

The firm also chooses the currency of its imported inputs that will serve as working capital and, correspondingly, the currency of its trade credit. Imported inputs and trade credit are available in the two international currencies, $d$ or $r$. The firm's choice of input mix affects the production function it will face in the next period. Because the interest rate

Figure 1: Each firm's choices and actions over time




charged for credit differs across currencies, and it is not known at the moment the choice is made, the firm's choice will have an impact on its future costs of production.

In period 1, the firm buys its inputs, both the imported working capital just discussed, as well as local non-credit inputs. The former must be paid ahead of production, while the others can be paid when the firm receives its revenues. Thus, the former require credit, which the firm obtains in a competitive market. The cost of credit differs across firms, reflecting their reputation or (out-of-equilibrium) temptation to default.

Finally, in period 2, each firm $j$ satisfies the demand in each of its markets $i$ given its sticky price. It collects its revenues, pays off its loans, and realizes its profits.

All risk is realized in period 1. This includes both the exchange rates that apply to imported inputs and to exports, as well as the costs of credit. Therefore, periods 1 and 2 could be collapsed into a single period, with a morning and an evening sub-periods, as is commonly done in DSGE models of working capital.[5]

## 2.2 Currency of working capital and credit

In period 0, each firm $j$ faces the following production technology:

$$x^j = \min\left\{\frac{x_r^j}{\eta^j}, \frac{x_d^j}{1-\eta^j}\right\}. \tag{1}$$

The firm can choose the relative shares of the two inputs, $x_r^j$ in currency $r$ and $x_d^j$ in currency $d$, by choosing $\eta^j \in [0,1]$.

The production function in period 1 is a Cobb-Douglas between this input $x^j$ and other

[5] Christiano and Eichenbaum (1995) is a classic reference.

local inputs $l^j$:

$$y^j = (x^j)^\alpha (l^j)^{1-\alpha}. \tag{2}$$

What distinguishes the $x^j$ inputs is that they are working capital that must be paid for ahead of production. Thus, the firm must borrow to finance these inputs, while the other inputs $l^j$ can be paid for later with the firm's revenues.

If the currency of this trade credit differed from the currency in which the firm borrows, then the firm would be exposed to exchange-rate risk. We assume that the firm will never want to bear this risk, so that when it chooses $\eta^j$ it is both choosing the currency of the inputs, as well as the currency of its trade credit to pay for them. Section 4.1 allows for these two choices to be different and shows that, in general, the firm will optimally choose to have them be the same.

## 2.3 Currency of pricing

In period 0, each firm $j$ chooses the currency of its sticky price in market $i$, among four possibilities:

$$\mathcal{P}_i^j \in \{PCP, LCP, DCP, RCP\}. \tag{3}$$

The first option is producer currency pricing (PCP). In that case, if the firm chooses a price $p_i^j$, this is what it will receive in domestic currency per unit sold. If instead it chooses local currency pricing (LCP), then $p_i^j$ is the price in the currency of the export market, while $p_i^j s_i$ is what it receives per unit sold, where $s_i$ is the exchange rate with the currency in that export market. A higher $s_i$ is an appreciation of the foreign currency, or a depreciation of the domestic currency against it. The firm can also choose a price in the dominant currency (DCP), so that its revenues are $p_i^j s_d$. Finally, and the focus of interest of this paper, it can choose to price in the rising currency (RCP) in market $i$, with revenues per unit sold in that market $p_i^j s_r$.

We assume that the vector $S$ collecting all the exchange rates across all the currencies is log-normally distributed, which will lead to exact analytical solutions. Section 4.2 relaxes this assumption, solving the model for a general distribution using a second-order approximation.

Let $\mu_i$ and $\sigma_i^2$ denote the mean and variance of the exchange rate of currency $i$ with respect to the domestic economy. It is straightforward to extend the model to allow any currency $i \in (0, 1)$ to potentially become an international currency, and derive the conditions for why this will not happen; section 3.3.4 discusses this further. For the two international currencies that we consider, we assume that $\mu_d = \mu_r$ and $\sigma_d = \sigma_r$. Clearly, if one of the two currencies is expected to appreciate relative to the other, or if it is significantly more stable, this will favor it in the choices of each firm. Carrying the terms that reflect this obvious advantage in the expressions that follow gives little insight. Moreover, in our empirical application, $r$ stands for the RMB and $d$ for the USD, currencies which, during our sample period, were partially pegged, so this restriction approximately held.

## 2.4 Cost of production

In order to pay for its working capital, the firm must borrow. Borrowing $q_d$ units in period 1 leads to a repayment of 1 unit in period 2. Instead, borrowing $q_r$ units in period 1, requires a payment of $\varepsilon^j$ in period 2. That is, while the interest rate on a $d$ loan is $1/q_d$, the interest rate on a $r$ loan is $\varepsilon^j/q_r$. Both are known at the time the loan is taken, but in the previous period, firm $j$ faces uncertainty on $\varepsilon^j$, which is drawn from a distribution $G^j(\varepsilon^j)$ in period 1.

The difference between these costs of credit plays an important role in the firm's choice of currency. For a start, the higher is the mean of $G^j(\varepsilon^j)$, the relatively more expensive it is, on average, to use $r$ credit than $d$ credit. This would arise if the dominant currency enjoys a safety premium, as deviations from uncovered interest parity would show up as $\varepsilon^j/q_r$ being on average significantly higher than $1/q_d$. Moreover, there is a spread of possible interest rates for borrowing in $r$ reflecting the more liquid capital markets in the $d$ currency. To a large extent, this is what defines $r$ as the dominant currency. Because the rising currency has a less liquid, or simply underdeveloped, credit market, choosing in period 0 to rely on $r$ credit in period 1 is risky. Assuming that the cost of borrowing in $d$ is known and the same for all firms is just for simplicity and plays no role in the analysis: it is the relative spread between $d$ and $r$ credit that matters.

The borrowed funds allow the firm to pay for working capital input, $x^j$. In period 1, $x_d^j$ and $x_r^j$ cost $\rho_d$ in $d$ currency, and $\rho_r$ in $r$ currency, respectively. We assume that $\rho_d$ or $\rho_r$ are known, but this is of no substance to the results. The non-credit inputs instead cost $w$ in domestic currency, which can be paid only when revenues get realized in period 2. In period 0, the firm faces uncertainty with respect to $w$, which is drawn from a log-normal distribution with covariances with the exchange rates of the two international currencies of $\sigma_{dw}$ and $\sigma_{rw}$. This source of uncertainty is common to all firms within the country.

We introduce one more assumption that is solely for convenience of the exposition. We assume that the correlation between the exchange rate in every market $s_i$, and the exchange rate of the $r$ and $d$ markets as well as $w$ inputs is the same for all $i$. Allowing for country-specific correlations changes none of our substantive results, but would require carrying many involved terms in each of the expressions, comparing an individual market's correlations with a weighted average of all other markets. While this assumption is absurdly unrealistic, there are no relevant economic lessons for this paper's goal that would come from relaxing it.

All combined, in period 1, the marginal cost of production for firm $j$ is:

$$C(\eta^j, \varepsilon^j, S, w) = \left[ \frac{\eta^j s_r \rho_r \left(\frac{\varepsilon^j}{q_r}\right) + (1-\eta^j) s_d \rho_d \left(\frac{1}{q_d}\right)}{\alpha} \right]^{\alpha} \left( \frac{w}{1-\alpha} \right)^{1-\alpha}. \tag{4}$$

## 2.5 Demand for goods

The firm is a monopolistic provider of its good to each of the foreign markets, and in all of them it faces a demand curve with a constant elasticity of $\theta$. Its sales depend on the currency in which it sets its price. If the firm follows LCP, then demand is given by: $y_i^j = (p_i^j)^{-\theta}$. If instead it sets a price according to PCP, then changes in the exchange rate will lead to changes in the price facing consumers and thus in their demand for the firm's product: $y_i^j = (p_i^j/s_i)^{-\theta}$. If it prices in the $d$ currency, then it is changes in the exchange rate between the $i$ market and $d$, so $s_d/s_i$ that shift demand: $y_i^j = (p_i^j s_d/s_i)^{-\theta}$. Symmetrically, with RCP: $y_i^j = (p_i^j s_r/s_i)^{-\theta}$

The literature on dominant currencies often assumes there are demand complementarities, so that the price set by other firms in market $i$ affects the demand for the good of firm $j$. This provides a force for the emergence and dominance of an international currency, as firms have an incentive to price in the same currency as other firms. Since this paper focuses on a different and complementary force, from matching the currency of credit to the currency of pricing, we isolate it by choosing to abstract from the complementarity channel. Section 4.2 re-derives the main results allowing for this complementarity.

## 2.6 The goal of the firm

The ex post profits of a firm in period 2 are given by the difference between revenues and costs. In the case of LCP, these are equal to the expression :

$$\pi^{LCP}(p_i^j, \eta^j, \varepsilon^j, S, w) = s_i (p_i^j)^{1-\theta} - C(\eta^j, \varepsilon^j, S, w)(p_i^j)^{-\theta}. \tag{5}$$

Similar expressions hold for the other three pricing cases.

Combining all the ingredients so far, the firm's problem is then:

$$\max_{\eta^j} \left( \int_0^1 \max_{\mathcal{P}_i^j} \max_{p_i^j} \left( \int \int \pi^{\mathcal{P}}(p_i^j, \eta^j, \varepsilon^j, S, w) dF(S) dG^j(\varepsilon^j) \right) di + ... \right) \tag{6}$$

The first inner maximization is the optimal price set by the firm. The second inner maximization is over the pricing currency for each market. The outer maximization is over the currency of credit for all the firm's operations. The expression omits the equivalent expressions for the $i = 0$ and $i = 1$ countries that have positive mass and issue the dominant and rising currencies (the full expression is in the appendix).

With full information, the firm would choose a price equal to a constant markup over marginal costs. The pricing currency would be irrelevant since, knowing the exchange rates, the firm would adjust the price to lead to the constant markup over marginal costs. As for the choice of credit, firms with $\varepsilon^j > (s_d/s_r)(\rho_d/\rho_r)(q_r/q_d)$ would choose the $d$ technology since its cost is lower, accounting for the cost of inputs, the costs of credit and the appreciation of the exchange rate.

Firms are not averse to uncertainty per se; they maximize expected profits and so are risk neutral. However, ex post deviations from a constant markup over marginal cost lead to lower profits. Shocks to exchange rates, cost of inputs, and borrowing costs, affect profits differently depending on the firm's choice of currency for credit and pricing.

## 2.7 Policies

The distribution of credit costs in the $r$ currency $G^j(\varepsilon^j)$ plays a central role in the model. The exorbitant privilege that an international currency enjoys is a low mean in this distribution, so that interest rates in this currency are lower than what a simple uncovered interest parity condition would suggest. Policies that create or help sustain such a privilege, including removing risk of default in that currency or reducing exchange-rate risk, can be seen as ways to shift this distribution to the left.

The introduction discussed how the FRB of New York in the 1910s and the People's Bank of China in the 2010s pursued many policies with the goal of increasing the liquidity of the market for overseas credit in the USD and the RMB, respectively. Whether these included de-regulating private activity or creating standardized contracts for these credits, all of these policies tried to lower the dispersion in the $G^j(\varepsilon^j)$ distribution.

One particular policy that we will use in the empirical analysis is a central bank swap line. It provides a way to borrow foreign currency at a pre-announced interest rate. A bank that has provided credit in foreign currency to a firm can go to the domestic central bank and borrow this foreign currency. The domestic central bank provides the monitoring services of the bank and its trade credits, while the foreign central bank provides the currency. Even if no one uses the swap line most of the time, their presence gives firms the certainty that the interest rate charged for working-capital credit in the foreign currency will never exceed the swap line rate.

Like other central bank lending programs, swap lines put a ceiling on interest rates, in this case on the interest rate at which firms can borrow the international currency.[6] Therefore, after a swap line is introduced for the $r$ currency at the rate $\varepsilon^{\text{swap}}/q_r$, the distribution of interest rates facing any firm shifts to:

$$\tilde{G}^j(\varepsilon^j) = \begin{cases} 1 & \text{if } \varepsilon^j \geq \varepsilon^{\text{swap}} \\ G^j(\varepsilon^j)/G^j(\varepsilon^{\text{swap}}) & \text{if } \varepsilon^j < \varepsilon^{\text{swap}} \end{cases} \tag{7}$$

For the currency of a small country, in which overseas credit is nonexistent, the introduction of the swap line could generate a significant volume of credit, all flowing through this central bank facility. The central bank would become the only creditor in this currency. Most central banks, or other government bodies, would not be willing to tolerate the large volume and credit risk associated with these activities. For a rising currency instead, a credit market already exists, but it is still illiquid so that the usual terms offered to firms can have a wide distribution. The swap line, by cutting the right tail of this distribution may end up being used quite infrequently and in small volumes. But, by removing these infrequent high rates, it can ex ante significantly affect the firms' inclination to borrow from banks in the rising currency, and other financial institutions' willingness to trade these in secondary markets.

The same result could be achieved through a direct government subsidy to the banks that give overseas credit for trade in the rising currency. This would directly shift the $G^j(\varepsilon^j)$ to the left. However, this would also come with potentially large costs to the government, as the subsidy is paid on all overseas credit. If the policy is successful, these costs would grow and could become very large. The swap line instead serves as a backstop, ex ante significantly lowering the risk of very high rates, but ex post only being used

[6]See Bahaj and Reis (2018) for further details on the operation of central bank swap lines, and evidence that this ceiling is quite effective.

infrequently. Other financial policies like de-regulation or creation of standard contracts, may have an initial fixed cost, but these do not rise after the jump-start of the currency.

Altogether, all of these policies broadly give rise to a distribution $\tilde{G}^j(\varepsilon^j)$ such that it is first-order stochastically dominated by the pre-policy distribution $G^j(\varepsilon^j)$. This is the policy experiment that we will study in the model.

# 3 Model predictions

With these ingredients, we now solve the problem in equation (6) and study how it changes with the introduction of central bank policies that shift $G^j(\varepsilon^j)$ to $\tilde{G}^j(\varepsilon^j)$.

## 3.1 The optimal currency of pricing

Start with the problem of a firm that has chosen $r$ credit ($\eta^j = 1$). (The choices of a firm that has chosen $d$ credit are symmetrical, with $d$ subscripts replacing the $r$ subscripts everywhere.) This firm needs to choose between the four pricing regimes for each market it sells to. This is a classic problem in the literature (Engel, 2006, Gopinath, Itskhoki and Rigobon, 2010), that is often solved with second-order approximations. Given our assumptions on functional forms and log-normality, it has an exact solution characterized in the following result that is proven in the appendix:

**Lemma 1.** *The choice of currency of pricing $\mathcal{P}$ in market $i$ by a firm $j$ that chooses r-credit ($\eta = 1$) has the following properties:*

*(a) RCP is always preferred to DCP as long as the correlation between $s_r$ and $s_d$ is smaller than one (otherwise the firm is indifferent).*

*(b) RCP is preferred to LCP in market $i$ if the variance of the local exchange rate is sufficiently high:*

$$\sigma_i^2 \geq \Phi \equiv \sigma_r^2 + 2\alpha(\sigma_{ir} - \sigma_r^2) + 2(1-\alpha)(\sigma_{iw} - \sigma_{rw})$$

*(c) RCP is preferred to PCP in market $i$ if the covariance of the country's non-credit marginal costs with the $r$ exchange rate is high enough:*

$$\sigma_{rw} \geq \Omega \equiv \sigma_r^2 \left( \frac{0.5 - \alpha}{1 - \alpha} \right).$$

Result (a) is natural. Since its marginal costs are partly denominated in the $r$ currency, but not in $d$ at all, there is no reason for the firm to use DCP. It would only do so if the $r$ and $d$ currencies were perfectly pegged to each other, in which case the firm would be indifferent between them in all its choices.

To understand result (b), start with the case where $\alpha = 1$ so that the marginal costs of the firm moves entirely with $s_r$. Then, $\Phi = -\sigma_r^2 + 2\sigma_{ir}$, which by the properties of covariance is always weakly smaller then $\sigma_i^2$. Thus, the firm would choose RCP in every market. Intuitively, given its desire to keep a constant markup to maximize profits, the firm will match the currency of its marginal cost and its revenues. A higher $\sigma_i^2$ relative to $\sigma_r^2$ makes the losses from LCP higher, while a higher covariance $\sigma_{ir}$ makes LCP resemble RCP more.

Consider now what happens if $\alpha < 1$. Some of the marginal costs depend on the non-credit input price $w$. If the covariance of $w$ with $s_i$ is positive, this provides an argument for LCP, while if the covariance of $w$ with $s_r$ is positive, this provides a further argument for RCP.

Result (c) compares RCP with PCP. If $\alpha > 1/2$, the condition always holds. This is because in this case, $s_r$ has a large enough impact on the costs of the firm that it wants to set its price in the $r$ currency as well. For a smaller $\alpha$, even though marginal costs vary with changes in $w$ as well, then as long as $\sigma_{rw}$ is large enough, again RCP will achieve higher expected profits. An interesting property of the solution is that $\Omega$ is the same for all markets $i$. Therefore, either RCP or PCP is used by firm $j$, but never both in different markets.

## 3.2 The optimal currency of credit

Taking as given its choice of pricing currency across markets, the firm chooses the currency of its working capital and of the credit it needs to buy it. The appendix proves the following novel result:

**Proposition 1.** *The optimal currency for working capital credit $\eta^j$ by firm $j$ has the following properties:*

*(a) It is bang-bang since the optimum $\eta^j \in \{0, 1\}$.*

(b) *The firm chooses r-credit ($\eta = 1$) if*

$$\left( \int \left( \varepsilon^j \right)^{\alpha} dG^j(\varepsilon^j) \right)^{1/\alpha} \leq \left( \frac{q_r}{q_d} \right) \left( \frac{\rho_d}{\rho_r} \right) \Psi.$$

(c) *The threshold $\Psi$ is the same for all firms and is a function of: (i) the share of markets for each choice of $\mathcal{P}_i^j$, (ii) the size of the r market, (iii) the covariance of $(S, w)$. The threshold $\Psi$ is larger, the larger are: the share of markets in which the firm uses RCP, the size of the r market, the covariance $\sigma_{rw}$.*

The first result follows from the general result that profit functions are quasi-convex in input prices. The firm will want to pick the input that has the lowest cost. There is no benefit to diversifying, since the firm cares only about expected profits.

The second result states that if the expected value of a concave function of the credit costs in $r$ currency is below a threshold that is common across firms, then the firm will choose $r$ credit. The first determinants of that threshold are the natural ones: low average interest rates and low input costs. The other determinants, captured in $\Psi$, the definition of which can be found in the appendix, are laid out in the third part of the proposition.

First, if the firm switches from using LCP to RCP for a marginal market, this raises $\Psi$ making it more likely that the threshold is met for currency $r$-credit. Intuitively, as a larger share of the firm's goods have revenues that depend on $s_r$, the firm has more incentive to have its costs depend on $s_r$ as well, through its working capital and credit. Second, in the $r$ export-market, by definition LCP=RCP for the firm. Increasing the size of this market has a similar effect as switching from LCP to RCP in another market: it raises the incentive to have the currency of credit costs line up with the currency of sales revenues. Third, if $\sigma_{rw}$ is larger, then the non-credit part of the firm's costs moves closer with $s_r$. With its intention of having a constant markup, the firm will want to have $r$ credit, thus matching the currency of all its inputs, and of its output price as well.[7]

## 3.3 The effect of central bank policy on currency adoption

Any of the central bank policies that we discussed—facilitating an exorbitant privilege, deregulation, creating a liquid market for credit in the currency, or introducing a central

[7] On top of this effect, a higher $\sigma_{rw}$ makes the firm use RCP in more of its markets following lemma 1, which further boosts this effect.

bank swap line—induce a shift in the distribution of credit costs in the $r$ currency, $G^j(\varepsilon^j)$ to $\tilde{G}^j(\varepsilon^j)$. The impact of the policies is then given by the following result.

**Proposition 2.** *A shift in the distribution of credit costs to $\tilde{G}^j(\varepsilon^j)$ that is first-order stochastically dominated by the previous one leads to the following results:*

*(a) For fixed $\eta^j = 1$, it has no effect on the choice of $\mathcal{P}$.*

*(b) Keeping fixed the $\mathcal{P}$ decision, some firms switch from $\eta^j = 0$ to $\eta^j = 1$.*

*(c) For firms that switch $\eta^j$, then in markets where $\sigma_i^2$ is high enough, they will choose RCP, as long as $\sigma_{rw}$ is high enough in the country for RCP to be preferable to PCP.*

*(d) The switch to RCP lowers $\Psi$, and so induces more firms to switch from $\eta^j = 0$ to $\eta^j = 1$.*

The distribution affects currency choices through the moment: $\left(\int \left(\varepsilon^j\right)^{\alpha} dG(\varepsilon^j)\right)^{1/\alpha}$. The central bank policies lower this sufficient statistic; their effectiveness is measured by how much they do so. In particular, the proposition lays out the extent to which the policy changes move the thresholds defined in the previous propositions.

Result (a) follows directly from lemma 1. None of its results depend on $G^j(.)$. Thus, for a given choice of credit currency, central bank policies have no effect on the currency of pricing.

In turn, result (b) follows directly from proposition 1. The central bank policies lower the expected costs of $r$ credit, making some firms cross the threshold in that proposition. These firms switch from $d$ credit to $r$ credit.

Result (c) applies lemma 1 to the firms that just switched from $d$ credit to $r$ credit. These firms will adopt RCP in some of their markets, as long as $\sigma_{rw}$ is high enough.

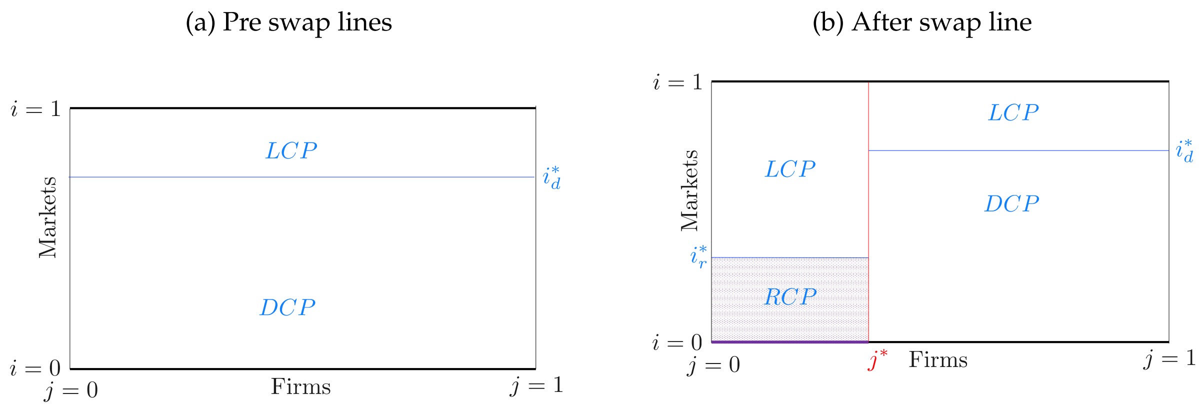
Finally, result (d) notes the second-round effects. As some firms choose the $r$ currency for pricing their goods, this makes the $r$ currency more attractive for credit as well given the result in proposition 1(c) .

Combining the introduction of a central bank swap line with this proposition leads to four empirical predictions.

### 3.3.1 Empirical prediction: jumpstarting R

Figure 2 represents the solutions of the model. On the horizontal axis are firms, ordered so that the higher is $j$, the higher is $\mathbb{E}^j\left(\left(\varepsilon^j\right)^{\alpha}\right)^{1/\alpha}$. Thus, associated with the threshold $\Psi$

Figure 2: The impact of the swap line



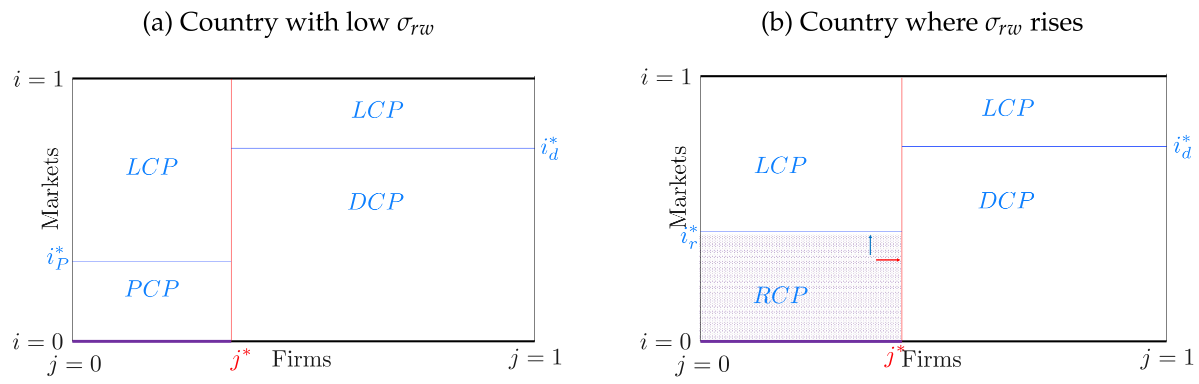

in proposition 1, there is a threshold $j^*$ such that firms with $j \leq j^*$ choose $\eta = 1$, and firms with $j > j^*$ choose $\eta = 0$. On the vertical axis are represented the markets to which each of these firms sell. Export markets differ in their $\sigma_i^2$, and we index these markets by the inverse of this variance. Then, the threshold $\Phi$ in lemma 1(b) translates into a threshold $i_r^*$ defined by $\sigma_{i_r^*}^2 = \Phi$. Firms with $i \leq i_r^*$ choose RCP, while the others choose LCP. Finally, the thick lines at $i = 0$ and $i = 1$ represent the $r$ market and the $d$ market, respectively.

Panel a) in the figure shows the case before the policy change. In this case, $j^* = 0$, and the $r$ currency is not used at all. All firms choose $d$ currency credit, and none of them chooses RCP. Rather, each firm uses DCP in some markets, and LCP in some other markets.

Panel b) shows the solution after policy lowers the expected credit costs of the $r$ currency. The threshold $j^*$ is now positive and so a mass of firms switches to $r$ currency credit. In some of their markets, those such that $i \leq i_r^*$, firms set a price in $r$ currency. The area of the purple rectangle then captures the usage of the $r$ currency. Both payments sent and received in the $r$ currency rise, as the two complement each other. The currency has jump-started into an international currency status.

Empirically, if the central bank of the $r$ currency country adopts a set of these policies, we should see that payments received and sent from other small open economies in the $r$ currency should rise. This happens not just with respect to the $r$ country but also to the other countries with which it trades.

Figure 3: Country variation




### 3.3.2 Empirical prediction: sorting on covariances

Figure 2 was drawn for a country that has sufficiently high $\sigma_{rw}$, above the threshold $\Omega$ in lemma 1(c). Therefore, firms did not opt for PCP after the switch, but rather for RCP in some markets.

The left panel of figure 3 shows instead what happens in a country when $\sigma_{rw}$ is lower than $\Omega$. Now, the firms that switch to $r$ credit choose PCP. The policy still jumpstarts the $r$ currency, but now to a smaller extent. In these countries, the $r$ currency is only used to make payments of inputs and the credit for them, but there are no payments received in $r$ currency from the sales of goods from any country besides the $r$ country in the $i = 0$ axis. This is represented in the figure by the purple area being now only in the (thick) segment of the horizontal axis.

In the model, $w$ stands for the cost of inputs that are not working capital and so do not require credit. A rough proxy for all the costs facing a firm, which will include those denominated in $r$ currency and funded by credit together with these other ones, is the producer price index. Therefore, one proxy for $\sigma_{rw}$ is the covariance between $s_r$ and the producer price index in that country. The empirical prediction is that sorting countries by this covariance, those for which it is higher will see a larger impact of policy on $r$ usage than those for which the covariance is smaller.

### 3.3.3 Empirical prediction: neighbors

Continuing to focus on $\sigma_{rw}$ leads to a separate prediction. A part of producer costs are the cost of inputs imported from other countries that are not paid on credit. Imagine now that as a result of policies adopted in those countries, their firms started pricing their exports more in the $r$ currency. This would result in more of the imports into the neighboring countries being priced in $r$ currency. As a result $\sigma_{rw}$ would be expected to rise.

Perhaps this increase in $\sigma_{rw}$ leads it to now exceed the $\Omega$ threshold, which it did not before. Then, the economy would shift from being described by panel (a) of figure 3 to being described by panel (b) of figure 2. The use of the $r$ currency would increase as firms switch from PCP to RCP. This is the first effect of $\sigma_{rw}$.

Panel (b) of figure 3 shows what happens when the country was already using the $r$ currency, so that this first effect is already taken into account. After a policy change in one of its neighbors, $\sigma_{rw}$ rises. From lemma 1 we know that $\Phi$ falls: more firms choose to invoice their sales in $r$ rather than in the local currency. The threshold $i_r^*$ rises. This is the second effect of a rise in $\sigma_{rw}$, and increases the r-currency box in the figure vertically.

Finally, the third effect comes from proposition 1: as $\sigma_{rw}$ rises, then $\Psi$ falls. This raises the threshold $j^*$ and so more firms choose $r$ credit. The r-currency box in the figure increases horizontally as well.

Combining all these changes, and their second round effects, the use of the $r$ currency in payments in and out of the country increases. The theory predicts that when a country signs a swap line with the $r$-currency central bank, we should expect its neighbors to make and receive more payments in the $r$ currency, even if they introduced no policies of their own.

#### 3.3.4 Empirical prediction: why so few international currencies?

The model is consistent with the fact that the vast majority of currencies in the world are not international currencies for three complementary reasons.

First, if $\sigma_r^2$ is large, then the currency will neither be used for credit nor for pricing of sales, according to the first two propositions. Having a stable exchange rate vis-à-vis most other countries is an important pre-condition for policy to have any effect on jumpstarting the international use of the currency.

Second, for most countries credit is expensive and illiquid in their currencies, so the $G^j(.)$ distributions are far to the right. For most currencies, the threshold $\Psi$ in proposition 1(b) is far from being met.

Third, the countries that issue these currencies are not large enough in international trade. As a result of proposition 1(c), their $\Psi$ itself is small and harder to clear.

If these countries were to try policies to jump-start their currencies, proposition 2 predicts they would fail because none of the thresholds would be overcome; they are too far to start with. The policies of the Federal Reserve in the 1910s and the People's Bank of China in the 2010s had a chance to succeed because they also came with sound monetary policy, large capital markets, and large weights in international trade in these countries to start with.

# 4 Model extensions

The model makes three assumptions that are worth further investigation. First, that the choice of $\eta^j$ pins down both the currency of the credit inputs, and that of the credit itself. Second, that there are special functional forms and distributions for shocks delivering analytical results. Third, that there are no demand complementarities. This sections relaxes each of them.

## 4.1 Currency of credit versus currency of inputs

When the firm chooses $\eta^j$ in period 0, it is choosing the type of input it will use in period 1 and what currency that input's price will be denominated in. We assume the firm also matches the currency of its borrowing with the currency of the input. However, the firm could choose to borrow in another currency and use it to buy the currency of the input at the exchange rate in period 1. This firm would then have to pay back the loan in period 2, which would require exchanging the currency of its sales to the currency of the credit. Insofar as the exchange rate in period 1 and 2 is different, then this creates exchange-rate risk. We now ask the question of whether the firm will want to have the currencies of inputs and credit match to avoid this risk, or not.

To answer it, the first new assumption is that the exchange rates at date 1, call them $\tilde{S}$ are not longer the same as in period 2, denoted by $S$ as before. Input $l^j$ is now chosen in period 2, once all uncertainty is realized, and to meet demand at the sticky price. Input $x^j$ though is paid for and chosen in period 1, using credit in either the $r$ currency, if $\zeta^j = 1$, or the $d$ currency if $\zeta^j = 0$. The realised cost of $x^j$, as function of both $\zeta^j$ and $\eta^j$, is now given by:

$$\eta^j \tilde{s}_r \left( \rho_r \frac{\varepsilon^j}{q_r} \zeta^j \frac{s_r}{\tilde{s}_r} + \frac{1}{q_d}(1-\zeta^j)\frac{s_d}{\tilde{s}_d} \right) + (1-\eta^j)\tilde{s}_d \left( \rho_d \frac{\varepsilon^j}{q_r} \zeta^j \frac{s_r}{\tilde{s}_r} + \frac{1}{q_d}(1-\zeta^j)\frac{s_d}{\tilde{s}_d} \right). \tag{8}$$

Note that if $\tilde{s}_r = s_r$ and $s_d = \tilde{s}_d$ then the firm would clearly just choose $\zeta^j$ such that the currency with the lowest expected cost of finance is used. Similarly, if $\eta^j = \zeta^j$, the risk from the intermediate exchange rates are perfectly hedged and we are back to the problem in the previous section.

We make a few auxiliary assumptions to make the analysis simpler: (i) all markets $i$ are identical and the firm does not sell to the $d$ and $r$ markets, (ii) $w$ is known, (iii) the marginal distributions of $s_r$ and $s_d$ are identical, as are those of $\tilde{s}_r$ and $\tilde{s}_d$, and (iv) all exchange rates follow random walks. Using these, the appendix shows the following:

**Proposition 3.** *The choices of currency of credit and currency of inputs are both bang-bang: $\eta \in \{0,1\}$ and $\zeta \in \{0,1\}$. A firm $j$ only chooses $(\eta, \zeta) = (0,0)$ or $(\eta, \zeta) = (1,1)$ so the currency of credit and the currency of the inputs coincide under LCP. The sufficient condition for the same to be true under PCP is $\sigma_{i\tilde{r}} = \sigma_{i\tilde{d}}$. The sufficient condition under RCP or DCP is $\sigma_{i\tilde{r}} = \sigma_{i\tilde{d}}$ and $\sigma_{\tilde{r}\tilde{d}} \geq 0$.*

The convexity of the profit function extends to both currency choices. The relevant question then is whether the firm ever chooses $(\eta, \zeta) = (1,0)$ or $(\eta, \zeta) = (0,1)$, that is to have the currency of its inputs and credit mismatched. The answer is that this is never the case under LCP and under mild conditions under PCP, DCP or RCP. The firm typically does not want to introduce a mismatch between part of its inputs and the credit, since this introduces variability in its marginal costs, and thus the markup resulting from sticky prices deviates from its optimal level more often.

The sufficient conditions in the proposition simply imply that the covariances between the exchange rates are such that the firm cannot hedge exchange rate driven fluctuations in markups by having a mismatch between its trade credit and the currency of inputs. These are stringent sufficient conditions; the full (lengthy) conditions are provided in the appendix.

## 4.2 Demand complementarities

This section studies three extensions to the main results. First, it allows the production function to be a generic homogeneous function of degree one, $F(x^j, l^j)$, as opposed to a Cobb-Douglas specification. Second, it allows for a generic demand function in market $i$ given by $Y(p_i^j/q_i)$ as opposed to a constant-elasticity of demand. Third, it allows for a generic local demand shifter $q^i$, which is stochastic. Following Arkolakis et al. (2018), this specification is quite general and accommodates demand complementarities: if other firms raise their price in a particular market, this can be captured by an increase in $q_i$. More relevant for the question in this paper, if more firms choose their prices in a particular currency, then the covariance of $q_i$ and that exchange rate will rise, and this provides an impetus for firm $j$ itself to also choose to invoice in this currency. The parameter $\lambda$ measures the elasticity of the firm's desired price to $q_i$ and so captures the strength of this strategic complementarity.

The fourth extension is that we now allow the vector of random variables $(S, w, Q)$ to follow any distribution. At the same time, all the results now follow from log-linear approximations around the non-stochastic price choice across markets. The (tedious) algebra is relegated to the appendix.

**Proposition 4.** *In the case where the demand curve exhibits strategic complementarities and the firm's production function is homogeneous of degree 1, to the second order, the model exhibits the following properties:*

*(a) The currency choice of invoice is is still determined by thresholds $\Phi$ and $\Omega$ as in lemma 1.*

*(b) If demand complementarities are sufficiently strong, $\lambda > 1/2$, an increase in $\sigma_{qr}$ makes it more likely that the firm will choose RCP over LCP.*

*(c) A shift in the distribution of credit costs to $\tilde{G}^j(\varepsilon^j)$ that is first-order stochastically dominated by the previous one still weakly leads to an increase in r-currency invoicing and r-currency credit as in proposition 2.*

The lessons in this paper are unchanged, especially as it concerns part (c), and the empirical predictions that followed from it.

At the same time, result (b) introduces a new mechanism. The presence of demand complementarities can introduce a new amplification force for the $r$ currency. If more firms start pricing in $r$ currency in market $i$ (raising $\sigma_{qr}$), the firm wants to follow them and price in $r$ currency as well. The larger is the demand complementarity, the stronger this force is.[8]

[8]Left out of our analysis are network externalities, whereby the benefits of the international currency rise as other firms and countries use it more. In the model, this would be captured by having $G(.)$ shift left as the thresholds for $r$ use rise. We do not model this link, since there is an extensive literature on these network effects, and they likely solely amplify the effect of the policy fundamentals that we focus on.

# 5 Data on RMB payments and swap lines

We bring two sources of data to the table. The first was hand collected from information by the PBoC and counter-party central banks on the details of their swap line agreements. The second comes from the SWIFT Institute and measures cross-border payments in RMB. We explain each in turn. Formal data definitions and sources are provided in section H of the appendix.

## 5.1 The PBoC swap lines

An RMB swap line is an agreement between the PBoC and a foreign central bank enabling it to borrow RMB. The typical agreement is for a fixed duration, usually setting out a 2- or 3-year period where the foreign central bank can choose to activate the swap line. So far, these agreements have tended to be renewed.

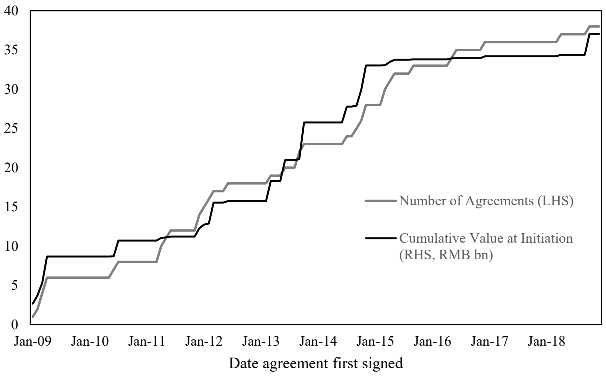
The contract approximately works as follows. The foreign central bank initiates the transaction by requesting to borrow RMB from the PBoC up to the notional amount of the contract, for a maturity that potentially goes from overnight to up to 2 years. If the PBoC approves and sends the RMB, the foreign central bank must gives the PBoC a deposit in its own currency as collateral (this is what makes the transaction a swap). At the end of the swap, the foreign central bank cancels the deposit (hence its own currency never enters circulation), and pays back to the PBoC the RMB borrowed plus a pre-agreed interest rate. Since no currency gets exchanged in the spot market, and the interest rate is fixed, the swap line has only credit risk, but no exchange-rate risk nor any interest-rate risk, just as in the model. The foreign central bank chooses its own procedures for how commercial banks in the foreign country can borrow the RMB. In some countries, like Singapore and Korea, there are standing RMB liquidity facilities available to commercial banks that are financed by the swap line, but other countries have more ad hoc arrangements.

This approach to central bank swap lines corresponds closely to how the Federal Reserve operates its swap facilities.[9] There is however an operational difference, given capital controls in China: the RMB is exchanged through an RMB settlement bank either locally (if the country has one), in Hong Kong, or potentially in another offshore RMB centre. The foreign central bank will have an account with the settlement bank, which itself has an account at the PBoC backing it. These settlement banks serve as intermediary

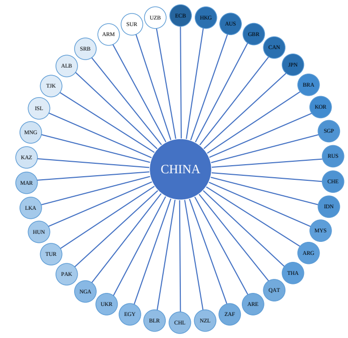
[9] On the USD swap lines, see Bahaj and Reis (2018).

Figure 4: The PBoC swap lines

(a) Swap lines: number and amounts




(b) The network of swap lines in 2018




correspondent banks, since foreign central banks (or banks) cannot have deposits at the PBoC.

We collected data on each swap line agreement signed or renewed by the PBoC starting from 2009, specifically covering the precise date in which it was signed and its notional amount. We compiled this information from the PBoC's official news releases and then cross checked with the foreign central bank's official communications. We complemented this with keeping track of when the swap lines were renewed or expired. There were 38 swap lines agreements in place in 2018, with Japan being the latest signatory. Using these data, we define the variable $\text{SwapLine}_{i,t}$ as an indicator that takes a value of one if country $i$ first signed a swap agreement with China at or before month $t$.[10]

Figure 4 shows the evolution of the number of outstanding swap lines and the sum of their notional amount. They have always been increasing. Most of the growth happens in the first half of the decade, with a significant slowdown after the RMB was included in the IMF basket in 2016. Still, after that period, the swap lines were not reversed and kept on being renewed. This evolution provides a potential null hypothesis for the empirical analysis: if the swap lines were signed mainly for symbolic purposes, perhaps related to the inclusion of the RMB to the SDR basket, we should find they have no effect on the actual use of the RMB.

The right panel shows the network of swap lines, where darker colors reflect a larger

[10] The swap line agreements sometimes lapse but are almost always renewed, sometimes with a gap of a few months. Hence, in our baseline specification we do not revert the indicator to zero if the swap line agreement officially lapses, since it would likely be renewed if it was needed, so the insurance aspect remains. Our results are robust to allowing for lapses.

committed amount. A table in the appendix lists all of the swap lines and their committed amounts. Unsurprisingly, large financial centres have large swap lines, as their banks and financial markets are used to provide credit in RMB to firms around the world. Other swap lines are dominated by countries with large trade or investment relations with China. However, the rush to show progress on this political endeavor means that the timing in which different swap lines were signed does not show an obvious pattern driven by economic fundamentals.

We do not have accurate data on the balances outstanding in each line at any point in time. In a non-exhaustive exercise, McDowell (2019) reports several instances of usage across 9 different countries. Mostly, it was used in operations related to RMB trade settlement, in the cases of Korea, Singapore, Turkey, Russia and Hong Kong. However, Pakistan, Argentina, Ukraine and Mongolia used it instead to pay for imports from China which would otherwise be funded in USD, or just swapped the RMB directly into USD to pay others.

## 5.2 SWIFT data on RMB payments

Our data source for cross-border payments is the Society for Worldwide Interbank Financial Telecommunication (SWIFT). It provides a network for financial institutions to send and receive messages to and from one another about financial transactions in a secure and standardized manner. SWIFT does not clear or settle payments, nor does it facilitate the transfer of funds; its messages are, for the most part, payment orders that are settled via correspondent accounts that banks hold with each other.

SWIFT accounts for a large share of cross-border transactions over our sample period (see Rice, von Peter and Boar (2020)). Hence, we view our data as representative both of overall payments and payments in RMB. China introduced its own Cross-Border Interbank Payment System (CIPS) in 2015 to improve cross-border RMB settlement and clearing by adopting common standards among participating banks. This system, and the network of participants, is still developing, and SWIFT messages are relied upon for the purpose of communicating with the system (see Deutsche Bank (2015)).

In the model, firms choose the currency of their borrowing and their invoicing. We observe instead the currency in which they make and receive cross-border payments. In principle, the currency used for invoicing and for settlement payments could be different, so long as there is no discrepancy in value. Likewise, in the model firms choose the currency of their credit, but they could perhaps be repaid the equivalent amount in a different currency. However, studies in this topic (e.g., Friberg and Wilander, 2008) find that, in 99% of the cases, the currency with which debt and payments are settled is the same as the currency of invoicing or the one in which the debt was written.

Our data is in the form of monthly bilateral payments broken down by country-pair, currency and message type. We exclude within-country messages. The sample covers 97 months, between October of 2010 and October of 2018. The data are aggregated at the country-pair level, and provides no information on who is making the payment (neither the bank nor the client). For most of what follows, we focus on payment orders: the combination of message types MT 103 and MT 202 in SWIFT, covering single customer and bank-to-bank payment message types, respectively.

For robustness, we also consider message type MT 400, which is an advice of payment: specifically it is a message from a bank acting on behalf of an importer, confirming to a bank acting on behalf of an exporter that payment has been made by the importer (the actual payments backing MT 400 are recorded separately in SWIFT as message types MT 202 or MT 103). This message type corresponds more closely to our model, since the messages are arising directly from trade. However, not every payment for international trade involves an MT 400 and SWIFT has less complete coverage of advice of payments.

With these data, we calculate our measure of interest: the RMB share in cross border payments sent and received per month per country. The aggregated data is displayed in figure 5 (together with the number of swap lines). The upward trend in the use of the RMB since the PBoC started its internationalization strategy is clearly visible, although, as with the number of swap lines growth, has leveled off in recent years.

## 5.3 A first look at the data: zeros

Figure 6 plots the RMB share of payments per country, averaged over all the months in the sample against the share of trade of each country with China. Some countries widely use the RMB, and also trade large amounts with China, like Mongolia. A few financial centres have large RMB usage as they will process payments from China, like Hong Kong or Singapore. For the vast majority of countries in the sample though, the use of the RMB at a monthly frequency is close to, or exactly, zero.[11]

[11] SWIFT reports a zero for a country pair if in that month there were less than 4 records across all currencies. So, if a country makes many payments to China but they are all in dollars, we would accurately observe RMB payments as a precise zero. If the country only makes 2 payments to China but they are all in RMB then the observation would be zero.

Figure 5: RMB share in global payments (and swap lines)

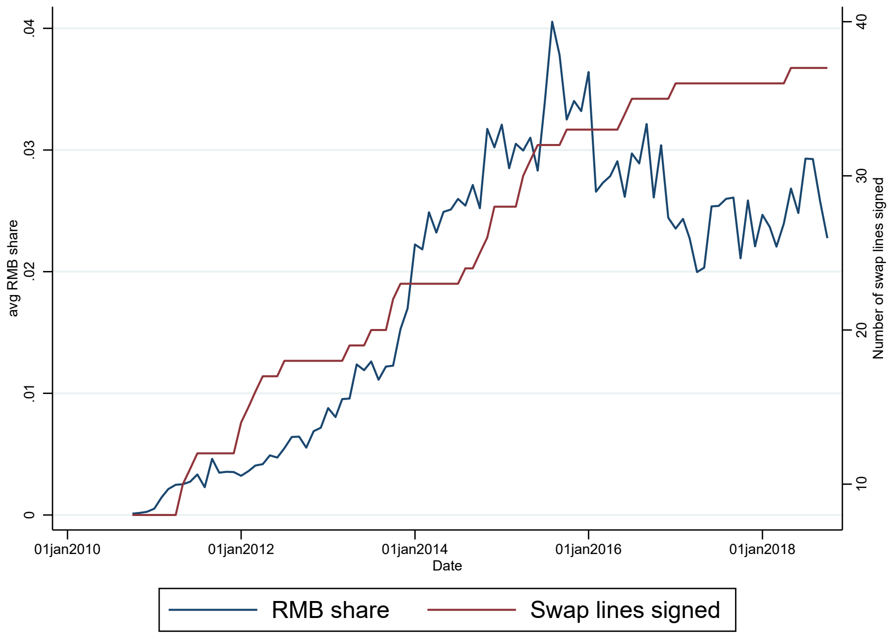



Figure 7 plots the median RMB share in cross-border payments for all countries that signed a swap agreement, against the number of months before and after the swap line was first introduced. Therefore, each observation in the plot shows the share of RMB payments across all countries that were at the same distance from signing (or having signed) an RMB swap line. The message from the figure is clear: the typical country that signed a swap line did not use the RMB at all before this policy took effect. Afterwards, the RMB starts being used and the effect grows over time and persists.

Taken together, figures 6 and 7 suggest that the swap lines trigger a jumpstart of the RMB as an international currency adopted for payments. The PBoC policy shows its effect on currency adoption for payments starting from zero. Therefore, in our analysis, the primary variable of interest will be an indicator that takes a value of 1 if the country makes or receives an RMB payment in a particular month, $1(\text{Rpayment}_{i,t} > 0)$. Both the theory and a first look at the data suggest that the effect of policy should show up along this extensive margin. For robustness, we will also look at the impact of policy on the share of cross border payments in RMB, $\text{Rshare}_{i,t}$.

Figure 6: RMB payments per country vs. trade with China

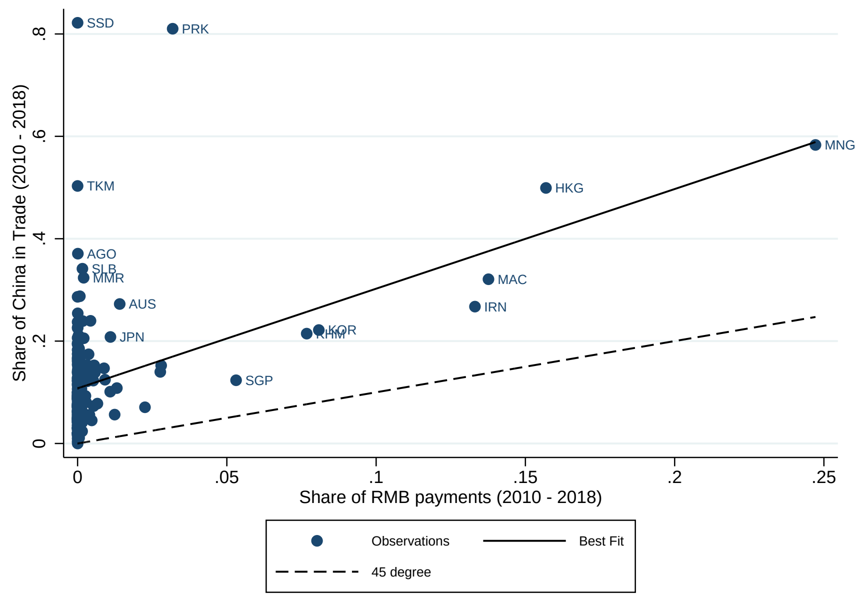
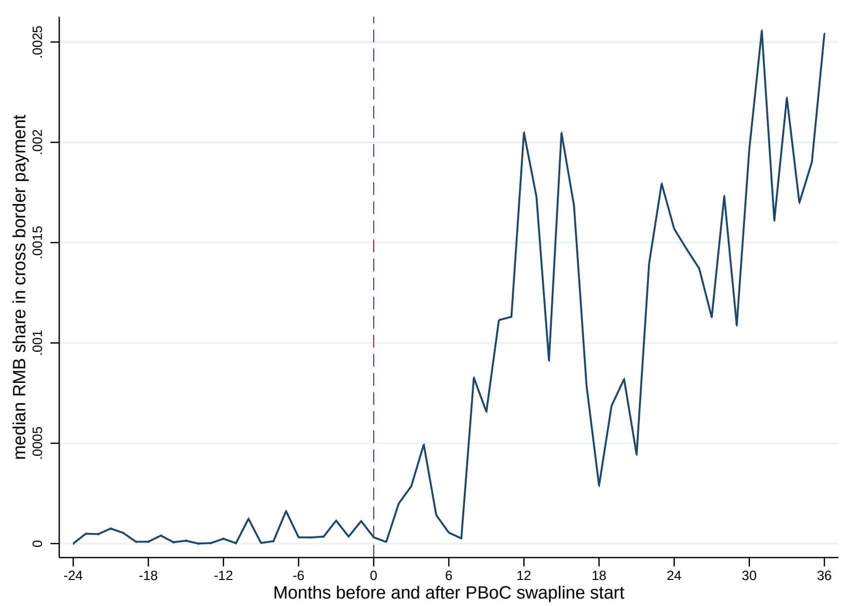



Figure 7: RMB payments share after a swap line is signed



## 5.4 Sample selection

Our model of a small open economy is better suited to approximate the functioning of smaller, less developed countries that are reliant on foreign currency credit for trade financing. Developed economies have a more sophisticated financial sector that can generate domestic trade credit and liquid currencies, and where foreign-exchange currency risk can be hedged. Moreover, the larger, more developed economies, are often hubs for international payments. This can lead to double counting of the same underlying transactions in SWIFT. One end-to-end transaction can show up as multiple orders as the payment gets routed through multiple banks in multiple jurisdictions. A payment from Chile to China may pass through New York, London and Singapore (potentially multiple times) and so recording payments to and from financial centres becomes misleading. Finally, larger economies are more likely to be affected by changes in other Chinese policies, or in world trade fundamentals, that would be confounding factors for the study of the swap lines.

Figure 6 shows that including in the sample the handful of countries with high shares of RMB usage would risk confusing the extensive margin RMB adoption with the intensive margin at work for these large financial or trade partners. We deal with these concerns in two ways. First, we consolidate Hong Kong and Macau into China. Second, in the baseline analysis, we exclude the financially developed countries and focus on developing countries, that average less than 30,000 PPP dollars of GDP per capita over the sample. This leaves us with a sample of 136 countries.[12]

## 5.5 Control variables to address reverse causality

A potential concern in the empirical investigation of swap lines is reverse causality. It is possible that the RMB usage in a given country increases due to some other factor besides the new policy and the country signs a swap line with the PBoC as a result of this increased demand for RMB. In a regression of the RMB payment dummy, $1(\text{Rpayment}_{i,t} > 0)$, on the introduction of a swap line, $\text{SwapLine}_{i,t}$, this third factor would show up in the residual, driving RMB usage while being correlated with the availability of a swap line, therefore biasing the estimates.

[12] We treat the euro area as it was composed at the start of the sample in 2010 as a single consolidated entity. Its per capita income exceeds the threshold and hence the member states are dropped. Countries that joined the euro area after 2010 are included separately but we do not treat their joining, and hence having access to the ECB's swap line, as equivalent to signing an agreement.

One way to address this concern is to include time fixed effects. To the extent that countries are relatively homogeneous, these can control for common trends in the adoption of the RMB and the expansion of the swap lines. Country fixed effects can similarly deal with time-invariant country characteristics that make a country more likely to both use the RMB and sign a swap line with the PBoC.

This still leaves the possibility of region-specific trends in RMB usage correlated with signing a swap line. These could be due to trade, political or productivity developments in the region and its relations with China. To proxy for these, let $\mathcal{N}_i$ denote the set of country $i$'s neighbors. We measure these as all the countries within 1000km of country $i$ if at least 5 are within that distance; if there are fewer than 5 countries within that distance, we include the nearest 5 countries to country $i$.[13] The control variable that measures the share of RMB used by country $i$'s neighbors is:

$$\text{Neighbor Use}_{i,t} = \frac{1}{|\mathcal{N}_i|} \sum_{j \in \mathcal{N}_i} 1(\text{Rpayment}_{j,t} > 0). \tag{9}$$

Another source of bias may stem from country-specific changes in the relationship with China. For instance, the signing of a swap line may occur around the same time as a trade agreement is signed, or there could be changes in tastes or technologies that induces the country to trade more with China. We control for this aspect by including a dummy for whether the country has a trade agreement with China as well as the log of dollar exports and imports from the country to China, and the ratio of Chinese imports and exports in the country's GDP.[14]

One can also think of other non-trade related capital flows that lead to increased RMB payments thanks to policies distinct from but correlated with the swap lines being signed. The RMB swap lines are often signed as part of a package of joint policies between China and the other country, and it is possible that these other policies are what spurred the use of the RMB. To address this issue, we add three additional measures of Chinese economic policy towards county $i$ as another set of controls. These measures take into account whether the country has a RMB clearing bank, whether it is a member of the Asian In-

[13]The distance is measured capital to capital using great circle distance. Alternative measures and thresholds give very similar results.

[14]It is worth noting that, when common trends are appropriately controlled for by fixed effects, there is no evidence that the swap lines are associated with an increase in trade with China either in absolute terms or in terms of a share of a country's total trade. This is inconsistent with the effect of the swap line being confounded by deepening economic linkages with China in general.

frastructure Investment Bank, and how large are the infrastructure investment flows from China as ratio of GDP, to account for the Belt and Road Initiative. The latter measure comes from the Chinese Global Investment Tracker of the American Enterprise Institute, keeping an account of large Chinese fixed investment projects globally. We consider both the amount announced in a particular month and the cumulative amount since the start of the sample.

Table 1 presents summary statistics for the different variables in our sample.

# 6 The empirical effect of the swap lines

Including time and country fixed effects, $\alpha_t$ and $\alpha_i$ respectively, as well as the controls with a vector of coefficients $\gamma$, our baseline specification is a linear probability regression:

$$1(\text{Rpayment}_{i,t} > 0) = \alpha_i + \alpha_t + \beta \times \text{SwapLine}_{i,t} + \gamma \times \text{Controls}_{i,t} + \text{error}_{i,t}. \tag{10}$$

The null hypothesis that the swap lines were just for political showmanship is that $\beta = 0$, while the main prediction from the theory in section 3.3.1 is that $\beta > 0$.

## 6.1 Baseline estimates

The first two columns of table 2 report the baseline estimates. The first column has no time fixed effects, so the 0.28 coefficient reflects the difference that was visible in figure 7. The second column includes time fixed effects. This specification has a difference-in-differences interpretation: it compares the RMB usage of the same country before and after signing a swap agreement relative to the usage of the RMB for the average country in the sample. Consistent with the large trends in RMB usage, the estimated coefficient falls by more than half compared to what it was without the time fixed effect, so that the availability of swap lines increases the probability that a country uses RMB by 13%. The effect is still large and supports the prediction of the theory.

The next three columns consider, incrementally, the additional controls described above. Column (3) includes RMB usage by neighbors, column (4) includes the four additional controls for trade with China, and column (5) adds the three measures of Chinese policy. Across all these specifications, the estimated coefficient remains quite stable, between 12% and 14%. This suggests that, after taking into account the time fixed effect, the omitted factors captured by these variables are not playing a major role in explaining the baseline coefficient.[15]

## 6.2 An instrumental variable approach

Any significant financial policy reform with a macroeconomic impact is endogenous in the sense that it was likely adopted in response to other economic circumstances. However, a valid instrumental variable to deal with the reverse causality problem does not need to be orthogonal to the country's macroeconomy. In our panel setting, it is only necessary that it is correlated with the signing of a swap line in a particular month, while not directly correlated with the share of RMB being used for payments.

The RMB swap lines are often signed during a state visit of the Chinese president to the foreign country. The precise timing of these visits is arguably exogenous, depending on the agenda of the Chinese politicians. By comparing countries that signed their swap line a few months before others, due to the state visit to their country happening earlier in time, we have some exogenous variation that can be used to isolate the impact of the swap lines.

Table 3 re-estimates the effects of the swap line in equation (10), but now using the date of the state visit as an instrument for the swap line. The first two columns show the results for the diff-in-diff specification, with fixed effects but no controls, while the second column includes all of the controls and interactions. The point estimate is significantly larger, with a 51-58% increase in the probability of using the RMB as a result of the swap lines.[16]

## 6.3 Neighbors

A subtle prediction from the theory highlighted in section 3.3.3 is that when a country's neighbor signs a swap line, then the country itself would see its share of RMB payments increasing. Investigating this possibility provides an alternative way to deal with the reverse causality problem. Arguably, the macroeconomic developments affecting any

[15] If we run the same regression but with the trade share with China on the left-hand side, the estimated effect of the swap line are precisely estimated to be close to zero. This is another argument against the omitted variables operating through a trade channel.

[16] Making the instrument starker, one could re-estimate the equation only on the sample of countries that both signed a swap line and received a state visit. This regression uses only the variation of the timing of the swap line signing as driven by the timing of the state visit. Unfortunately, because the sample is much smaller, the estimates are imprecise, and do not allow us to draw any conclusion.

economy and its use of the RMB are unlikely to have an influence on their neighbor's policy choices.

Table 4 shows regressions where the treatment or dummy variable is now Neighbor Use$_{i,t}$. In the first column, the table shows the baseline specification with fixed effects. The second column includes a new control Far Country Use$_{i,t}$. This is the complement of Neighbor Use$_{i,t}$: i.e. the usage of the RMB by countries that are not neighbors. By including this control we get closer to a difference-in-differences interpretation in that we see how the swap line affects RMB usage in the vincinity of the country holding the rest of the world fixed. The second set of columns (3) and (4) excludes from the regression the countries that signed a swap line themselves at any point in the sample, to more radically isolate the pure effect of the neighbors.

The effect is not as large, with only a 5-10% probability that the RMB becomes an international currency in that country as a result of its neighbor signing a swap line. Nevertheless, the effect is statistically significant at the 1% level. Moreover, the theory predicts that the effect of a neighbor signing a swap line should not be as large as that of the country itself signing a swap line.

## 6.4 Sorting on covariances

A third prediction of the model laid out in section 3.3.2 is that a larger correlation of the country's producer price index with the RMB exchange rate should be associated with a stronger predicted impact of the swap line on using the RMB. To investigate if this is so, we sort the full sample in two sub-samples, according to whether the correlation is above or below the median. Measures of producer prices are not available at a monthly frequency for many of the developing countries in our sample, and as a result the sample size falls significantly.

Table 5 shows the results for the two samples both for the baseline differences-in-differences regression and including all controls. In a third specification, we measure RMB usage according only to payments received, as the theory suggested that the impact of a higher $\sigma_{rw}$ should be to raise credit in RMB but not necessarily sales denominated in it. Consistently with the theory, the effects of the swap line are larger in countries with a higher covariance across all specifications.

## 6.5 Robustness and other results

We now look at other patterns in the data beyond the main predictions of the theory.

### 6.5.1 Excluding China

The currency of a country can be considered international if it is used for transactions between two other countries. Table 6 repeats the baseline regressions excluding the use of the RMB in payments to and from China. The effects are only slightly smaller, between 11 and 12%.

### 6.5.2 Different types of payment

The theory included two dimensions: the usage of the $r$-currency for credit and for sales. Table 7 splits payments into three types. First, it considers payments received only, corresponding to the choice of $\mathcal{P}$ in the model. Second, it consider payments sent only, as in the choice of $\eta$ in the model. Third, among the SWIFT message types for payment, it considers only the ones that are associated with trade credit (MT 400).

Across payments sent and received, the results are quite stable, between 13% and 14%. The results on MT 400 are much smaller and only marginally statistically significant. The sample changes for this last set of regressions as fewer countries report any MT 400 payments.

### 6.5.3 Impact on shares

In table 8, we replace the left-hand side variable of the regression. Instead of an indicator for whether the RMB is used, we look at the actual share of RMB usage. This includes both the extensive margin from jumpstarting the currency, as well as the intensive margin of usage.

Consistent with the theory, the effects of policy are not as precisely estimated. Nevertheless, they suggest about a 0.4% increase in the RMB share due to the swap line. Unsurprisingly, this matches the rise we see in figure 7.

### 6.5.4 The persistence of the effects

The statistical tests so far decisively reject the null hypothesis that the swap lines were signed only for their political significance in the negotiations with the IMF to have the

RMB join the SDR's basket, and show that they had real economic effects. Nevertheless, we now consider the possibility that this was the main driver of the Chinese policy, in which case the estimated effects should have vanished once the RMB became part of the SDR in 2015.

Figure 4 already cast serious doubts on this hypothesis on the side of policy: the number of swap lines and their notional amount did not decline once the SDR basket was revised. On the side of outcomes, table 9 separates the effects of a swap line between the first 12 months, and the remaining 12-36 months after the swap line was signed. If anything, the effects tend to be larger at longer horizons, which would refute the hypothesis of political grandstanding. This is also consistent with the model in the paper, if the currency decisions by firms are staggered over time.[17]

# 7 Conclusion

This paper suggested that international currency status depends on the financial cost of working capital credit, and that this is affected by central bank policies. A model of the complementarity between the currency choice for credit and the currency choice for invoicing revealed thresholds for key economic variables that a rising currency must meet before it becomes used overseas. Most currencies do not meet these thresholds, justifying why so few are international. But for some, policy can shift the thresholds and so jumpstart the currency. Empirically, we used the RMB swap lines to test for the effects of policy, and for the role of these thresholds and complementarities. We estimated a 13 percentage point increase in the probability of a country making or receiving RMB payments as a result of the swap lines, and an increase in the RMB share of payments of 0.4 percentage points.

Drawing the comparison with the similar actions of the Federal Reserve one century ago, the RMB is today much less used than the USD was back in 1925. In part, perhaps this is because the RMB capital markets continue to be subject to many controls. Moreover, there was no shock threatening the USD in the last decade the way that World War I closed the GBP market. The experience of the USD suggests that Chinese policymakers can do much more if they want the RMB to rise further.

Our goal was positive rather than normative. Whether the swap lines were the best tool to trigger the jumpstart, and whether the costs of policies do not outweigh the ben-

[17] The panel remains balanced: there are no new swap lines after 2016, and the data ends in October 2018.

efits of having an international currency, are questions that we did not ask or answer. Neither did we address whether the central bank is the right agent to be pursuing this promotion, how should it interact with fiscal authorities, and what are the implications for the exchange rate regime and capital flows. These are all left for future work.

# References

**Amiti, Mary, and David E. Weinstein.** 2011. "Exports and Financial Shocks." *Quarterly Journal of Economics*, 126(4): 1841–1877.

**Amiti, Mary, Oleg Itskhohi, and Jozef Konings.** 2019. "Dominant Currencies: How Firms Choose Currency Invoicing and Why It Matters." Mimeo, Princeton University.

**Arkolakis, Costas, Arnaud Costinot, Dave Donaldson, and Andrés Rodríguez-Clare.** 2018. "The Elusive Pro-Competitive Effects of Trade." *The Review of Economic Studies*, 86(1): 46–80.

**Bacchetta, Philippe, and Eric van Wincoop.** 2005. "A Theory of the Currency Denomination of International Trade." *Journal of International Economics*, 67(2): 295 – 319.

**Bahaj, Saleem, and Ricardo Reis.** 2018. "Central Bank Swap Lines." *CEPR discussion paper 13003*.

**Bank, Deutsche.** 2015. "Chinese Central Bank Has Introduced CIPS." Global Transaction Banking.

**Bruno, Valentina, and Hyun Song Shin.** 2019. "Dollar Exchange Rate as a Credit Supply Factor – Evidence from Firm-Level Exports." *BIS Working Paper No. 819*.

**Chahrour, Ryan, and Rosen Valchev.** 2020. "The International Medium of Exchange." Mimeo, Boston College.

**Chen, Natalie, Wanyu Chung, and Dennis Novy.** 2018. "Vehicle Currency Pricing and Exchange-Rate Pass-Through." *CEPR discussion paper 13085*.

**Christiano, Lawrence J., and Martin Eichenbaum.** 1995. "Liquidity Effects, Monetary Policy, and the Business Cycle." *Journal of Money, Credit and Banking*, 27(4): 1113–1136.

**Corsetti, Giancarlo, Meredith Crowley, and Lu Han.** 2018. "Invoicing and Pricing-to-Market: Evidence on International Pricing by UK Exporters." *CEPR discussion paper 13282*.

**Eichengreen, Barry.** 2011. *Exorbitant Privilege: The Rise and Fall of the Dollar and the Future of the International Monetary System.* Oxford University Press.

**Eichengreen, Barry, and Domenico Lombardi.** 2017. "RMBI or RMBR? Is the Renminbi Destined to Become a Global or Regional Currency?" *Asian Economic Papers*, 16(1): 35–59.

**Eichengreen, Barry, Arnaud Mehl, and Livia Chitu.** 2017. *How Global Currencies Work: Past, Present, and Future.* Princeton University Press.

**Engel, Charles.** 2006. "Equivalence Results for Optimal Pass-Through, Optimal Indexing to Exchange Rates, and Optimal Choice of Currency for Export Pricing." *Journal of the European Economic Association*, 4(6): 1249–1260.

**Eren, Egemen, and Semyon Malamud.** 2019. "Dominant Currency Debt." *BIS Working Paper 783*.

**Friberg, Richard, and Fredrik Wilander.** 2008. "The Currency Denomination of Exports – A Questionnaire Study." *Journal of International Economics*, 75(1): 54–69.

**Goldberg, Linda S., and Cédric Tille.** 2008. "Vehicle currency use in international trade." *Journal of International Economics*, 76(2): 177–192.

**Goldberg, Linda S., and Cédric Tille.** 2016. "Micro, macro, and strategic forces in international trade invoicing: Synthesis and novel patterns." *Journal of International Economics*, 102: 173–187.

**Gopinath, Gita.** 2015. "The International Price System." In *Inflation Dynamics and Monetary Policy*. Jackson Hole Symposium:Federal Reserve Bank of Kansas City.

**Gopinath, Gita, and Jeremy C Stein.** 2018. "Banking, Trade, and the Making of a Dominant Currency." *NBER working paper 24485*.

**Gopinath, Gita, Emine Boz, Camila Casas, Federico J. Díez, Pierre-Olivier Gourinchas, and Mikkel Plagborg-Møller.** 2020. "Dominant Currency Paradigm." *American Economic Review*, 110(3): 677–719.

**Gopinath, Gita, Oleg Itskhoki, and Roberto Rigobon.** 2010. "Currency Choice and Exchange Rate Pass-Through." *American Economic Review*, 100(1): 304–36.

**Gourinchas, Pierre-Olivier, Hélène Rey, and Maxime Sauzet.** 2019. "The International Monetary and Financial System." *Annual Review of Economics*, 11(1): 859–893.

**Ilzetzki, Ethan, Carmen M. Reinhart, and Kenneth S. Rogoff.** 2020. "Why is the Euro Punching Below Its Weight?" *Economic Policy*, forthcoming.

**Klenow, Peter J., and Jonathan L. Willis.** 2016. "Real Rigidities and Nominal Price Changes." *Economica*, 83(331): 443–472.

**Maggiori, Matteo.** 2017. "Financial Intermediation, International Risk Sharing, and Reserve Currencies." *American Economic Review*, 107(10): 3038–71.

**Maggiori, Matteo, Brent Neiman, and Jesse Schreger.** 2019. "The Rise of the Dollar and Fall of the Euro as International Currencies." *AEA Papers and Proceedings*, 109: 521–26.

**Mayer, Thierry, and Soledad Zignago.** 2011. "Notes on CEPII's distances measures: The GeoDist database." *CEPII Working Paper 2011-25*.

**McDowell, Daniel.** 2019. "The (Ineffective) Financial Statecraft of China's Bilateral Swap Agreements." *Development and Change*, 50(1): 122–143.

**Mukhin, Dmitry.** 2018. "An Equilibrium Model of the International Price System." University of Wisconsin mimeo.

**Prasad, Eswar.** 2015. *The Dollar Trap: How the U.S. Dollar Tightened Its Grip on Global Finance.* Princeton University Press.

**Prasad, Eswar.** 2016. *Gaining Currency: The Rise of the Renminbi.* Oxford University Press.

**Rice, Tara, Goetz von Peter, and Codruta Boar.** 2020. "On the Global Retreat of Correspondent Banks." *BIS Quarterly Review*, 37–52.

# Appendix – For Online Publication

## A Profit functions and optimal prices

The profits for firm $j$ in market $i$ under the different pricing regimes are:

$$\text{With LCP:} \quad \pi_i^{LCP}(p_i^j, \eta^j, \varepsilon^j, S, w) = \left[s_i p_i^j - C(\eta^j, \varepsilon^j, S, w)\right] (p_i^j)^{-\theta} \tag{A1}$$

$$\text{With PCP:} \quad \pi_i^{PCP}(p_i^j, \eta^j, \varepsilon^j, S, w) = \left[p_i^j - C(\eta^j, \varepsilon^j, S, w)\right] \left(\frac{p_i^j}{s_i}\right)^{-\theta} \tag{A2}$$

$$\text{With RCP:} \quad \pi_i^{RCP}(p_i^j, \eta^j, \varepsilon^j, S, w) = \left[s_r p_i^j - C(\eta^j, \varepsilon^j, S, w)\right] \left(\frac{p_i^j s_r}{s_i}\right)^{-\theta} \tag{A3}$$

$$\text{With DCP:} \quad \pi_i^{DCP}(p_i^j, \eta^j, \varepsilon^j, S, w) = \left[s_d p_i^j - C(\eta^j, \varepsilon^j, S, w)\right] \left(\frac{p_i^j s_d}{s_i}\right)^{-\theta} \tag{A4}$$

Firms choose prices to maximize the period-0 expectation of these expressions delivering:

$$\text{With LCP:} \quad p_i^{LCP}(\eta^j) = \frac{\theta}{\theta-1} \frac{\mathbb{E}\left[C(.)\right]}{\mathbb{E}\left[s_i\right]} \tag{A5}$$

$$\text{With PCP:} \quad p_i^{PCP}(\eta^j) = \frac{\theta}{\theta-1} \frac{\mathbb{E}\left[C(.) s_i^\theta\right]}{\mathbb{E}\left[s_i^\theta\right]} \tag{A6}$$

$$\text{With RCP:} \quad p_i^{RCP}(\eta^j) = \frac{\theta}{\theta-1} \frac{\mathbb{E}\left[C(.) \left(\frac{s_r}{s_i}\right)^{-\theta}\right]}{\mathbb{E}\left[s_r^{1-\theta} s_i^\theta\right]} \tag{A7}$$

$$\text{With DCP:} \quad p_i^{DCP}(\eta^j) = \frac{\theta}{\theta-1} \frac{\mathbb{E}\left[C(.) \left(\frac{s_d}{s_i}\right)^{-\theta}\right]}{\mathbb{E}\left[s_d^{1-\theta} s_i^\theta\right]} \tag{A8}$$

Hence, we obtain profits for firm $j$ in market $i$, given an optimal price choice, as a function of $\eta^j$ and the exogenous variables:

$$\pi_i^{LCP*}(\eta^j) = \mathbb{E}\left[s_i\left(p_i^{LCP}(.)\right)^{1-\theta} - C(.)(p_i^{LCP}(.))^{-\theta}\right] \tag{A9}$$

$$\pi_i^{PCP*}(\eta^j) = \mathbb{E}\left[\left(p_i^{PCP}(.)\right)^{1-\theta}(s_i)^{\theta} - C(.)\left(p_i^{PCP}(.)\right)^{-\theta}(s_i)^{\theta}\right] \tag{A10}$$

$$\pi_i^{RCP*}(\eta^j) = \mathbb{E}\left[s_i^{\theta}(p_i^{RCP}(.))^{1-\theta}(s_r)^{1-\theta} - C(.)\left(p_i^{RCP}(.)\right)^{-\theta}(s_i/s_r)^{\theta}\right] \tag{A11}$$

$$\pi_i^{DCP*}(\eta^j) = \mathbb{E}\left[s_i^{\theta}(p_i^{DCP}(.))^{1-\theta}(s_d)^{1-\theta} - C(.)\left(p_i^{DCP}(.)\right)^{-\theta}(s_i/s_d)^{\theta}\right] \tag{A12}$$

# B Proof of lemma 1

Since $\eta^j = 1$, marginal costs are equal to

$$C(1, \varepsilon^j, S, w) = \left(\frac{s_r\rho_r(\varepsilon^j/q_r)}{\alpha}\right)^{\alpha}\left(\frac{w}{1-\alpha}\right)^{1-\alpha}. \tag{A13}$$

Plugging optimal prices when $\eta^j = 1$ into the profit functions in equations (A9)-(A12) and simplifying gives the expressions for maximized profits under LCP, RCP, DCP and PCP:

$$\pi^{LCP*}(\eta^j) = \Xi\,\mathbb{E}\left[s_i\right]^{\theta}\mathbb{E}\left[(s_r)^{\alpha}(w)^{1-\alpha}\right]^{(1-\theta)} \tag{A14}$$

$$\pi^{PCP*}(\eta^j) = \Xi\,\mathbb{E}\left[s_i^{\theta}\right]^{\theta}\mathbb{E}\left[(s_r)^{\alpha}(w)^{1-\alpha}(s_i)^{\theta}\right]^{1-\theta} \tag{A15}$$

$$\pi^{RCP*}(\eta^j) = \Xi\,\mathbb{E}\left[(s_r)^{1-\theta}(s_i)^{\theta}\right]^{\theta}\mathbb{E}\left[(s_r)^{\alpha-\theta}(w)^{1-\alpha}(s_i)^{\theta}\right]^{1-\theta} \tag{A16}$$

$$\pi^{DCP*}(\eta^j) = \Xi\,\mathbb{E}\left[(s_d)^{1-\theta}(s_i)^{\theta}\right]^{\theta}\mathbb{E}\left[(s_r)^{\alpha}(w)^{1-\alpha}(s_i/s_d)^{\theta}\right]^{1-\theta} \tag{A17}$$

$$\text{where}\quad \Xi \equiv \frac{1}{\theta-1}\left(\frac{\theta}{\theta-1}\right)^{-\theta}\mathbb{E}\left[\left(\frac{\rho_r\varepsilon^j/q_r}{\alpha}\right)^{\alpha}\left(\frac{1}{1-\alpha}\right)^{1-\alpha}\right]^{1-\theta}. \tag{A18}$$

With these elements, the proof of the different parts is as follows:

**Part a)** For a fixed choice of credit currency equal to the rising currency, $\eta^j = 1$, the firm prefers RCP over DCP in market $i$ if:

$$\pi_i^{RCP*}(1) \geq \pi_i^{DCP*}(1) \quad \Leftrightarrow \tag{A19}$$

$$\mathbb{E}\left[s_r^{1-\theta} s_i^{\theta}\right]^{\theta} \mathbb{E}\left[s_r^{\alpha-\theta} w^{1-\alpha} s_i^{\theta}\right]^{1-\theta} \geq \mathbb{E}\left[s_d^{1-\theta} s_i^{\theta}\right]^{\theta} \mathbb{E}\left[s_r^{\alpha} w^{1-\alpha} s_d^{-\theta} s_i^{\theta}\right]^{1-\theta} \tag{A20}$$

Under the assumption that all of these random variables follow log-normal distributions and that the $r$ and $d$ currencies have the same expected rate of depreciation, due to the assumed peg, this simplifies to:

$$(2\alpha - 1)\,\sigma_r^2 + \sigma_d^2 \geq 2\left[\alpha\sigma_{rd} + (1-\alpha)(\sigma_{dw} - \sigma_{rw})\right] \tag{A21}$$

We further assumed that the $r$ and $d$ currencies were similar to each other in the sense that $\sigma_r^2 = \sigma_d^2$ and $\sigma_{dw} = \sigma_{rw}$. The expression then becomes:

$$\frac{\sigma_{rd}}{\sigma_r \sigma_d} \leq 1, \tag{A22}$$

which proves the proposition.

**Part b)** The firm prefers RCP over LCP in market $i$ if:

$$\pi_i^{RCP*}(1) \geq \pi_i^{LCP*}(1) \;\; \Leftrightarrow \tag{A23}$$

$$\mathbb{E}\left[s_r^{1-\theta} s_i^{\theta}\right]^{\theta} \mathbb{E}\left[s_r^{\alpha-\theta} w^{1-\alpha} s_i^{\theta}\right]^{1-\theta} \geq \mathbb{E}\left[s_i\right]^{\theta} \mathbb{E}\left[s_r^{\alpha} w^{1-\alpha}\right]^{1-\theta} \tag{A24}$$

Assuming log-normal distributions again, and that the means of the logs of $s_r$ and $s_d$ are the same, this expression simplifies to:

$$\sigma_i^2 \geq \sigma_r^2 + 2\left[\alpha(\sigma_{ir} - \sigma_r^2) + (1-\alpha)(\sigma_{iw} - \sigma_{rw})\right] \equiv \Phi. \tag{A25}$$

This proves the result.

**Part c)** The firm prefers RCP over PCP if:

$$\pi_i^{RCP*}(1) \geq \pi_i^{PCP*}(1) \;\; \Leftrightarrow \tag{A26}$$

$$\mathbb{E}\left[s_r^{1-\theta} s_i^{\theta}\right]^{\theta} \mathbb{E}\left[s_r^{\alpha-\theta} w^{1-\alpha} s_i^{\theta}\right]^{1-\theta} \geq \mathbb{E}\left[s_i^{\theta}\right]^{\theta} \mathbb{E}\left[s_r^{\alpha} w^{1-\alpha} s_i^{\theta}\right]^{1-\theta} \tag{A27}$$

Under the log-normal distribution and the assumption of equal means, this can be simplified to

$$(2\alpha - 1)\sigma_r^2 + 2(1-\alpha)\sigma_{rw} \geq 0 \quad \Leftrightarrow \quad \sigma_{rw} \geq \sigma_r^2 \left(\frac{0.5-\alpha}{1-\alpha}\right) \equiv \Omega. \tag{A28}$$

# C Define profits across all markets for the firm

The profits of the firm come from aggregating across all of its markets. Completing the expression in equation (6), each firm $j$ chooses its currency of credit $\eta^j$ to maximize the profit function $\Pi^j(\eta^j)$ that is defined by:

$$\Pi^j(\eta^j) = \int_{\Delta^{LCP}(\eta^j)} \pi_i^{LCP*}(\eta^j)di + \int_{\Delta^{PCP}(\eta^j)} \pi_i^{PCP*}(\eta^j)di + \int_{\Delta^{RCP}(\eta^j)} \pi_i^{RCP*}(\eta^j)di$$
$$+ \int_{\Delta^{DCP}(\eta^j)} \pi_i^{DCP*}di + \delta_0 \pi_0^{RCP*}(\eta^j) + \delta_1 \pi_1^{DCP*}(\eta^j) \tag{A29}$$

The four sets in the integrals correspond to the the partition of the firm's markets according to the pricing technology the firm uses in them: $\Delta^{LCP} \cup \Delta^{PCP} \cup \Delta^{RCP} \cup \Delta^{DCP} = (0,1)$. The mass in each of these sets depends on $\eta^j$.

The terms $\pi_0^{RCP*}$ and $\pi_1^{DCP*}$ correspond to profits in the $r$ and $d$ markets respectively. These markets have mass $\delta_0$ and $\delta_1$. The expression above assumes that sales to the $r$ and $d$ markets always employ LCP, which of course is the same as RCP and DCP, respectively.

# D Proof of proposition 1

**Part a)** Let the part of marginal costs that depends on the $x^j$ input be denoted by:

$$c(\eta^j) = \eta^j s_r \rho_r(\varepsilon^j/q_r) + (1-\eta^j)s_d(\rho_d/q_d). \tag{A30}$$

For the general choice of $\eta^j$, optimal profits with LCP in market $i$ can be written as:

$$\pi_i^{LCP*}(c(\eta^j)) = \frac{1}{\theta-1}\left(\frac{\theta}{\theta-1}\right)^{-\theta} \mathbb{E}\left[s_i\right]^{\theta} \mathbb{E}\left[\left(\frac{c(\eta^j)}{\alpha}\right)^{\alpha}\left(\frac{w}{1-\alpha}\right)^{1-\alpha}\right]^{1-\theta}. \tag{A31}$$

These two functions are continuous and differentiable. Crucially, given our assumptions, the $\pi_i^{LCP*}(.)$ function only depends on $\eta^j$ via the $c(.)$ function. The chain rule then implies that:

$$\frac{\partial^2 \pi_i^{LCP*}(c)}{\partial \eta^2} = \frac{\partial^2 \pi_i^{LCP*}(c)}{\partial c^2} \left(\frac{\partial c(\eta)}{\partial \eta}\right)^2 + \frac{\partial \pi_i^{LCP*}(c)}{\partial c} \frac{\partial^2 c(\eta)}{\partial \eta^2}. \tag{A32}$$

The last term on the right-hand side is zero since the $c(\eta^j)$ function is linear. It is easy to see that $\partial^2 \pi_i^{LCP*}(c)/\partial c^2 \geq 0$. Therefore: $\frac{\partial^2 \pi_i^{LCP*}(c)}{\partial \eta^2} \geq 0$.

Now consider the firm's total profit function across all markets laid out under equation (A29). Start by focussing on the first two terms of the expression for $\Pi(\eta)$:

$$\int_{\Delta^{LCP}(\eta))} \pi_i^{LCP*}(\eta))di + \int_{\Delta^{PCP}(\eta)} \pi_i^{PCP*}(\eta)di. \tag{A33}$$

Using Leibniz's rule, the first derivative of this expression is:

$$\int_{\Delta^{LCP}} \frac{\partial \pi_i^{LCP*}}{\partial \eta} di + \int_{\Delta^{PCP}} \frac{\partial \pi_i^{PCP*}}{\partial \eta} di + \underbrace{\pi_k^{LCP*} - \pi_k^{PCP*}}_{=0}, \tag{A34}$$

where $k$ is the marginal market at which the firm was just indifferent between these two pricing options before the change. Thus, the last term must be zero. Taking another round of derivatives:

$$\underbrace{\int_{\Delta^{LCP}} \frac{\partial^2 \pi_i^{LCP*}}{\partial \eta^2} di + \int_{\Delta^{PCP}} \frac{\partial^2 \pi_i^{PCP*}}{\partial \eta^2} di}_{>0} + \underbrace{\frac{\partial \pi_k^{LCP*}}{\partial \eta} - \frac{\partial \pi_k^{PCP*}}{\partial \eta}}_{>0} \tag{A35}$$

where we assumed that the the size of the set $\Delta^{LCP*}$ increased at the expense of the set $\Delta^{PCP*}$. The first two terms are strictly positive since we already showed above that the profit functions in individual markets are convex. The following difference of two terms is also positive: since the marginal market switched to LCP, it must be that the difference in marginal profits is positive. If instead the change in $\eta$ decreased the size of $\Delta^{LCP*}$, then the difference of terms would reserve signs, which would then also be positive.

Considering the other two integrals, over the DCP and RCP markets, leads by the same logic to the same conclusion. Each of the profit functions within non-marginal markets is convex, and each of the multiple combinations of positive marginal markets all must be positive because at the optimum, any switcher has the property that the first derivative of the profit function under the new pricing currency exceeds that of the first derivative under the old pricing currency. Finally, adding in markets 0 and 1 keeps the result, since profits in those markets are convex in $\eta^j$ and by assumption the firm always chooses the equivalent of LCP.

Altogether, we conclude that the overall profits of the firm across all the markets is a convex function of $\eta$. Since the firm is risk neutral it follows that the optimal choice is at one of the bounds, either $\eta^j = 0$ or $\eta^j = 1$.

**Part b)** This proof for now assumes that PCP is not used, so $\Delta^{PCP}(\eta) = \emptyset$. This would be justified by the condition in lemma 1(c) holding. Moreover, it follows from lemma 1(a) that if $\eta = 1$, then $\Delta^{DCP}(1) = \emptyset$ and conversely that $\Delta^{RCP}(0) = \emptyset$.

Given the result in part (a), the condition for $r$ credit to be chosen by firm $j$ is that $\Pi^j(1) \geq \Pi^j(0)$. This translates into:

$$\left[\left(\frac{\rho_R/q_R}{\alpha}\right)^{\alpha} \int \left(\varepsilon^j\right)^{\alpha} dG^j(\varepsilon^j)\right]^{1-\theta} A_r \geq \left[\left(\frac{\rho_D/q_D}{\alpha}\right)^{\alpha}\right]^{1-\theta} A_d \tag{A36}$$

where the two terms are defined as:

$$A_r = \int_{\Delta^{RCP}(1)} \mathbb{E}\left[s_R^{1-\theta} s_i^{\theta}\right]^{\theta} \left(\mathbb{E}\left[s_r^{\alpha-\theta} w^{1-\alpha} s_i^{\theta}\right]\right)^{1-\theta} di + \int_{\Delta^{LCP}(1)} \mathbb{E}[s_i]^{\theta}\, \mathbb{E}\left[s_r^{\alpha} w^{1-\alpha}\right]^{1-\theta} di$$
$$+ \delta_0\, \mathbb{E}[s_r]^{\theta} \left(\mathbb{E}\left[s_r^{\alpha} w^{1-\alpha}\right]\right)^{1-\theta} + \delta_1\, \mathbb{E}[s_d]^{\theta}\, \mathbb{E}\left[s_r^{\alpha} w^{1-\alpha}\right]^{1-\theta} \tag{A37}$$

$$A_d = \int_{\Delta^{DCP}(0)} \mathbb{E}\left[s_d^{1-\theta} s_i^{\theta}\right]^{\theta} \left(\mathbb{E}\left[s_d^{\alpha-\theta} w^{1-\alpha} s_i^{\theta}\right]\right)^{1-\theta} di + \int_{\Delta^{LCP}(0)} \mathbb{E}\left[s_i\right]^{\theta}\, \mathbb{E}\left[s_d^{\alpha} w^{1-\alpha}\right]^{1-\theta} di$$
$$+ \delta_0\, \mathbb{E}\left[s_r\right]^{\theta}\, \mathbb{E}\left[s_d^{\alpha} w^{1-\alpha}\right]^{1-\theta} + \delta_1\, \mathbb{E}[s_d]^{\theta} \left(\mathbb{E}\left[s_d^{\alpha} w^{1-\alpha}\right]\right)^{1-\theta} \tag{A38}$$

Rewriting this produces the result in the proposition where $\Psi = (A_r/A_d)^{\frac{1}{(\theta-1)\alpha}}$.

**Part c)** From the expressions for $A_d$ and $A_r$ above, it follows right away that $\Psi$ depends on: (i) the shares of the markets for each choice of $\mathcal{P}^i$, that is the $\Delta^{\mathcal{P}}$, (ii) the size of the $r$ market, that is $\delta_0$, (iii) the covariance matrix of $(S, w)$, which appears after evaluating the expectations in the integrals above and recalling that all variables are log normal.

An increase in $\Delta_1^{RCP}$—and the corresponding fall in $\Delta_1^{LCP}$—raises $A_r$ from equation (A37): it must be that the profits under RCP are larger than under LCP for the shift to have happened. It does not change $A_d$ from equation (A38). Thus, it raises $\Psi$.

An increase in $\delta_0$ raises $A_r$ by $\mathbb{E}[s_r]^{\theta} \left(\mathbb{E}\left[s_r^{\alpha} w^{1-\alpha}\right]\right)^{1-\theta}$. It raises $A_d$ by the amount $\mathbb{E}[s_r]^{\theta}\, \mathbb{E}\left[s_d^{\alpha} w^{1-\alpha}\right]^{1-\theta}$. Using the properties of log normal distributions, one can show that the increase in $A_r$ is larger than the increase in $A_d$. Therefore, $\Psi$ rises.

Finally, take $\delta_0$ to be close to zero. Then, an increase in $\sigma_{rw}$ has no effect on $A_d$. However, it raises $A_r$. Thus, it raises $\Psi$.

# E Proof of proposition 2

Result (a) follows directly from lemma 1 since the $G(.)$ distribution appears nowhere. Result (b) follows directly from proposition 1 in its part (b). Result (c) follows from lemma 1 in its part (b) and (c). Result (d) follows from proposition 1 in its part (c).

# F Proof of proposition 3

Define the firm's realised cost of buying one unit of input $x^j$ as:

$$c(\eta^j, \zeta^j) = \eta^j \tilde{s}_r \rho_r \left( \frac{\varepsilon^j}{q_r} \zeta^j \frac{s_r}{\tilde{s}_r} + \frac{1}{q_d}(1-\zeta^j)\frac{s_d}{\tilde{s}_d} \right) + (1-\eta^j)\tilde{s}_d \rho_d \left( \frac{\varepsilon^j}{q_r} \zeta^j \frac{s_r}{\tilde{s}_r} + \frac{1}{q_d}(1-\zeta^j)\frac{s_d}{\tilde{s}_d} \right). \tag{A39}$$

By substituting $c(\eta^j, \zeta^j)$ for $c(\eta^j)$ and repeating the steps in part a) of the proof of proposition 1 in Appendix D, it is straightforward to show that for any given choice of $\eta^j$ the problem is convex in $\zeta^j$ and vice versa under LCP. The same holds in other pricing regimes. Hence the firm will make four potential choices: $(\eta^j, \zeta^j) \in \{(0,0), (0,1), (1,0), (1,1)\}$.

The proof of the proposition proceeds as follows. We always assume that the firm prefers $(\eta^j, \zeta^j) = (1,1)$ to $(\eta^j, \zeta^j) = (0,0)$, or $r$ as opposed to $d$ as its currencies of credit and capital. We ask whether it will choose $\zeta_j = 1$ if $\eta_j = 1$. That is, we derive the sufficient conditions for the firm to always choose $r$ credit, if it is buying $r$-denominated capital.

The proof is broken down by pricing regimes.

**The sufficient condition under LCP.** Since all markets are the same, under LCP the firm's profits are given by:

$$\pi^{LCP*}(\eta^j) = \mathbb{E}\left[ s_i (p_i^{LCP})^{1-\theta} - \left( \frac{c(\eta^j, \zeta^j)}{\alpha} \right)^{\alpha} \left( \frac{w}{1-\alpha} \right)^{1-\alpha} (p_i^{LCP})^{-\theta} \right]. \tag{A40}$$

Using the definition of optimal prices from appendix B we obtain:

$$p_i^{LCP} = \frac{\theta}{\theta-1}\frac{\mathbb{E}\left[\left(\frac{c(\eta^j,\zeta^j)}{\alpha}\right)^{\alpha}\right]}{\mathbb{E}\left[s_i\right]}\left(\frac{w}{1-\alpha}\right)^{1-\alpha}. \tag{A41}$$

Dropping terms that do not depend on choices, the firm chooses $\eta^j, \zeta^j$ to solve:

$$\max_{\eta^j,\zeta^j}\left\{\mathbb{E}\left[\left(c(\eta^j,\zeta^j)\right)^{\alpha}\right]^{1-\theta}\right\}. \tag{A42}$$

Therefore, using the definition of $c(.)$ in equation (A39), the firm will choose $(\eta,\zeta) = (1,1)$ over $(\eta,\zeta) = (0,0)$ if:

$$\mathbb{E}\left[\left(\rho_r(\varepsilon^j/q_r)s_r\right)^{\alpha}\right] \leq \mathbb{E}\left[((\rho_d/q_d)s_d)^{\alpha}\right]. \tag{A43}$$

Since $s_r$ and $s_d$ have the same marginal distributions, this amounts to $\mathbb{E}\left[\varepsilon_j^{\alpha}\right] \leq \left(\frac{\rho_d q_r}{\rho_r q_d}\right)^{\alpha}$.

Now, imagine that $\eta^j = 1$, and determined the optimal choice of $\zeta^j$. Convexity means the firm will go for a bang-bang solution. In particular, it will choose $\zeta^j = 1$ if:

$$\mathbb{E}\left[\left(\rho_r(\varepsilon^j/q_r)s_r\right)^{\alpha}\right] \leq \mathbb{E}\left[\left(\tilde{s}_r(\rho_d/q_d)\frac{s_d}{\tilde{s}_d}\right)^{\alpha}\right]. \tag{A44}$$

Using the log-normal distribution assumption:

$$\mathbb{E}\left[\varepsilon_j^{\alpha}\right] \leq \left(\frac{\rho_d q_r}{\rho_r q_d}\right)^{\alpha}\frac{\mathbb{E}\left[s_d^{\alpha}\tilde{s}_d^{-\alpha}\tilde{s}_r^{\alpha}\right]}{\mathbb{E}\left[s_r^{\alpha}\right]} \tag{A45}$$

$$= \exp\left\{\alpha(\mu_d-\mu_r) + \frac{\alpha^2}{2}(\sigma_d^2-\sigma_r^2) + \alpha(\tilde{\mu}_r-\tilde{\mu}_d) + \frac{\alpha^2}{2}\sigma_{\tilde{r}}^2 + \frac{\alpha^2}{2}\sigma_{\tilde{d}}^2 - \alpha^2\sigma_{\tilde{r}\tilde{d}} - \alpha^2\sigma_{d\tilde{d}} + \alpha^2\sigma_{d\tilde{r}}\right\}.$$

With common marginals ($\sigma_d^2 - \sigma_r^2 = \mu_d - \mu_r = \tilde{\mu}_r - \tilde{\mu}_d = 0$), this simplifies to:

$$\mathbb{E}\left[\varepsilon_j^{\alpha}\right] \leq \left(\frac{\rho_d q_r}{\rho_r q_d}\right)^{\alpha}\exp\left\{\frac{\alpha^2}{2}\sigma_{\tilde{r}}^2 + \frac{\alpha^2}{2}\sigma_{\tilde{d}}^2 - \alpha^2\sigma_{\tilde{r}\tilde{d}} + \alpha^2(\sigma_{d\tilde{r}} - \sigma_{d\tilde{d}})\right\}. \tag{A46}$$

Recall that the condition under which the firm will choose $(\eta^j,\zeta^j) = (1,1)$ against $(\eta^j,\zeta^j) = (0,0)$ is $\mathbb{E}\left[\varepsilon_j^{\alpha}\right] \leq \left(\frac{\rho_d q_r}{\rho_r q_d}\right)^{\alpha}$. The sufficient condition for the firm to prefer

$(\eta^j,\zeta^j)=(1,1)$ to $(\eta^j,\zeta^j)=(1,0)$ is then:

$$\sigma^2_{\tilde{r}}+\sigma^2_{\tilde{d}}-2\sigma_{\tilde{r}\tilde{d}}+2(\sigma_{d\tilde{r}}-\sigma_{d\tilde{d}})\geq 0. \tag{A47}$$

Using the facts that $\text{Var}(\tilde{s}_r-\tilde{s}_d)=\sigma^2_{\tilde{d}}+\sigma^2_{\tilde{r}}-2\sigma_{\tilde{d}\tilde{r}}\geq 0$ to replace the first three terms, we obtain:

$$\text{Var}(\tilde{s}_r-\tilde{s}_d)+2(\sigma_{d\tilde{r}}-\sigma_{d\tilde{d}})\geq 0. \tag{A48}$$

The steps can easily be repeated for the symmetric case where the firm chooses between $(\eta^j,\zeta^j)=(0,0)$ and $(\eta^j,\zeta^j)=(0,1)$. The condition is now:

$$\text{Var}(\tilde{s}_r-\tilde{s}_d)+2(\sigma_{r\tilde{d}}-\sigma_{r\tilde{r}})\geq 0. \tag{A49}$$

**The sufficient condition under PCP.** Analogous steps to those taken above under PCP, lead to the objective:

$$\max_{\eta^j,\zeta^j}\left\{\mathbb{E}\left[\left(c(\eta^j,\zeta^j)\right)^{\alpha}s_i^{\theta}\right]^{1-\theta}\right\}, \tag{A50}$$

and to the condition $\mathbb{E}\left[\varepsilon_j^{\alpha}\right]\leq\left(\frac{\rho_d q_r}{\rho_r q_d}\right)^{\alpha}\exp\left\{\alpha\theta(\sigma_{id}-\sigma_{ir})\right\}$ for the firm to choose $(\eta^j,\zeta^j)=(1,1)$ over $(\eta^j,\zeta^j)=(0,0)$.

If $\eta^j=1$, what is the optimal choice of $\zeta^j$? As before, the firm will go for a bang-bang solution. It will choose $\zeta^j=1$ if:

$$\mathbb{E}\left[\left(\rho_r(\varepsilon^j/q_r)s_r\right)^{\alpha}s_i^{\theta}\right]\leq\mathbb{E}\left[\left(\tilde{s}_r(\rho_d/q_d)\frac{s_d}{\tilde{s}_d}\right)^{\alpha}s_i^{\theta}\right]\quad\Leftrightarrow \tag{A51}$$

$$\mathbb{E}\left[\varepsilon_j^{\alpha}\right]\leq\left(\frac{\rho_d q_r}{\rho_r q_d}\right)^{\alpha}\frac{\mathbb{E}_0\left[s_d^{\alpha}\tilde{s}_d^{-\alpha}\tilde{s}_r^{\alpha}s_i^{\theta}\right]}{\mathbb{E}_0\left[s_r^{\alpha}s_i^{\theta}\right]} \tag{A52}$$

With the assumption that $s_d$ and $s_r$ have the same marginals as do $\tilde{s}_d$ and $\tilde{s}_r$, this becomes:

$$\mathbb{E}\left[\varepsilon_j^{\alpha}\right]\leq\left(\frac{\rho_d q_r}{\rho_r q_d}\right)^{\alpha}\exp\left\{\frac{\alpha^2}{2}\sigma^2_{\tilde{r}}+\frac{\alpha^2}{2}\sigma^2_{\tilde{d}}-\alpha^2\sigma_{\tilde{r}\tilde{d}}+\alpha^2(\sigma_{d\tilde{r}}-\sigma_{d\tilde{d}})+\alpha\theta(\sigma_{di}+\sigma_{i\tilde{r}}-\sigma_{ir}-\sigma_{i\tilde{d}})\right\}. \tag{A53}$$

Using the condition for $r$ currency to be used over $d$ currency in both choices, the sufficient condition for choosing $\zeta^j=1$ is:

$$\text{Var}(\tilde{s}_r-\tilde{s}_d)+2(\sigma_{d\tilde{r}}-\sigma_{d\tilde{d}})+\frac{2\theta}{\alpha}(\sigma_{i\tilde{r}}-\sigma_{i\tilde{d}})\geq 0. \tag{A54}$$

**The sufficient condition under RCP.** Now consider a firm acting under RCP. Assume that the condition $\mathbb{E}_0\left[\varepsilon_j^\alpha\right] \le \left(\frac{\rho_d q_r}{\rho_r q_d}\right)\exp\left\{\alpha\theta(\sigma_{id}-\sigma_{rd}-\sigma_{ir})\right\}$ is satisfied; this means that the firm will choose $(\eta^j,\zeta^j)=(1,1)$ over $(\eta^j,\zeta^j)=(0,0)$.

Again, imagine $\eta^j=1$, and derive the optimal choice of $\zeta^j$? Following the analogous steps to the cases above, the firm it will choose $\zeta^j=1$ if:

$$\mathbb{E}\left[\left(\rho_r(\varepsilon^j/q_r)\right)^\alpha (s_r)^{\alpha-\theta}(s_i)^\theta\right] \le \mathbb{E}\left[\left(\tilde{s}_r(\rho_d/q_d)\frac{s_d}{\tilde{s}_d}\right)^\alpha (s_r)^{-\theta}(s_i)^\theta\right] \quad \Leftrightarrow \tag{A55}$$

$$\mathbb{E}\left[\varepsilon_j^\alpha\right] \le \left(\frac{\rho_d q_r}{\rho_r q_d}\right)^\alpha \frac{\mathbb{E}\left[(s_d)^\alpha(\tilde{s}_d)^{-\alpha}(\tilde{s}_r)^\alpha(s_i)^\theta(s_r)^{-\theta}\right]}{\mathbb{E}\left[(s_r)^{\alpha-\theta}(s_i)^\theta\right]}. \tag{A56}$$

Since $s_d$ and $s_r$ have the same marginals as $\tilde{s}_D$ and $\tilde{s}_R$, the condition becomes:

$$\mathbb{E}\left[\varepsilon_j^\alpha\right] < \left(\frac{q_r}{\rho q_d}\right)^\alpha \times$$
$$\exp\left\{\frac{\alpha^2}{2}\sigma_{\tilde{r}}^2+\frac{\alpha^2}{2}\sigma_{\tilde{d}}^2-\alpha^2\sigma_{\tilde{r}\tilde{d}}+\alpha^2(\sigma_{d\tilde{r}}-\sigma_{d\tilde{d}})+\alpha\theta(\sigma_{id}+\sigma_{i\tilde{r}}-\sigma_{i\tilde{d}}-\sigma_{ir})-\alpha\theta(\sigma_{dr}+\sigma_{r\tilde{r}}-\sigma_{r\tilde{d}})\right\}. \tag{A57}$$

Since $\mathbb{E}\left[\varepsilon_j^\alpha\right] \le \left(\frac{\rho_d q_r}{\rho_r q_d}\right)\exp\{\alpha\theta(\sigma_{id}-\sigma_{rd}-\sigma_{ir})\}$, this becomes:

$$\sigma_{\tilde{r}}^2+\sigma_{\tilde{d}}^2-2\sigma_{\tilde{r}\tilde{d}}+2(\sigma_{d\tilde{r}}-\sigma_{d\tilde{d}})+\frac{2\theta}{\alpha}(\sigma_{i\tilde{r}}-\sigma_{i\tilde{d}})+\frac{2\theta}{\alpha}(\sigma_r^2+\sigma_{r\tilde{d}}-\sigma_{r\tilde{r}}) \ge 0, \tag{A58}$$

with a symmetric condition for $\eta^j=0$ under DCP.

**Completing the proof.** We have now derived three sufficient conditions, under the three different currency pricing regimes, for the firm to choose $\zeta_j=1$ if $\eta_j=1$, assuming the firm already prefers $(\eta^j,\zeta^j)=(1,1)$ to $(\eta^j,\zeta^j)=(0,0)$). To repeat, these are:

$$\text{With LCP:}\quad \mathrm{Var}(\tilde{s}_r-\tilde{s}_d)+2(\sigma_{d\tilde{r}}-\sigma_{d\tilde{d}}) \ge 0 \tag{A59}$$

$$\text{With PCP:}\quad \mathrm{Var}(\tilde{s}_r-\tilde{s}_d)+2(\sigma_{d\tilde{r}}-\sigma_{d\tilde{d}})+\frac{2\theta}{\alpha}(\sigma_{i\tilde{r}}-\sigma_{i\tilde{d}}) \ge 0 \tag{A60}$$

$$\text{With RCP:}\quad \mathrm{Var}(\tilde{s}_r-\tilde{s}_d)+2(\sigma_{d\tilde{r}}-\sigma_{d\tilde{d}})+\frac{2\theta}{\alpha}(\sigma_{i\tilde{r}}-\sigma_{i\tilde{d}})+\frac{2\theta}{\alpha}(\sigma_r^2+\sigma_{r\tilde{d}}-\sigma_{r\tilde{r}}) \ge 0 \tag{A61}$$

Symmetric conditions hold for the firm always choosing $\zeta_j=0$ if $\eta_j=0$.

Start with the LCP case. Recall the assumption that the exchange rates are random walks. It implies that:

$$\sigma_{d\tilde{d}} = \sigma^2_{\tilde{d}}, \quad \sigma_{r\tilde{r}} = \sigma^2_{\tilde{r}}, \quad \sigma_{r\tilde{d}} = \sigma_{\tilde{r}d} = \sigma_{\tilde{r}\tilde{d}}. \tag{A62}$$

Hence

$$\text{Var}(\tilde{s}_r - \tilde{s}_d) + 2(\sigma_{d\tilde{r}} - \sigma_{d\tilde{d}}) = \sigma^2_{\tilde{d}} + \sigma^2_{\tilde{r}} - 2\sigma_{\tilde{d}\tilde{r}} + 2(\sigma_{\tilde{d}\tilde{r}} - \sigma^2_{\tilde{d}}). \tag{A63}$$

Under the assumption that $\tilde{s}_d$ and $\tilde{s}_r$ share the same marginal distribution, we have $\sigma^2_{\tilde{d}} + \sigma^2_{\tilde{r}} - 2\sigma^2_{\tilde{d}} = 0$. Hence a firm choosing LCP will never choose $(\eta, \zeta) = (1, 0)$. Symmetrically, it will never choose $(\eta, \zeta) = (0, 1)$.

Turning to the PCP case, if the firm chooses $(\eta^j, \zeta^j) = (1, 1)$ over $(\eta^j, \zeta^j) = (1, 0)$ under LCP, the sufficient condition for the firm to do so under PCP is $\sigma_{i\tilde{r}} \geq \sigma_{i\tilde{d}}$. Symmetrically, the sufficient condition for the firm not choosing $(\eta, \zeta) = (0, 1)$ is $\sigma_{i\tilde{r}} - \sigma_{i\tilde{d}} \leq 0$. Hence, $\sigma_{i\tilde{r}} = \sigma_{i\tilde{d}}$ is the sufficient condition for the firm to always choose $(\eta, \zeta) = (0, 0)$ or $(\eta, \zeta) = (1, 1)$ under PCP.

Last, under RCP, and since we assumed that $\sigma_{i\tilde{r}} = \sigma_{i\tilde{d}}$, the sufficient condition is $\sigma^2_r + \sigma_{r\tilde{d}} - \sigma_{r\tilde{r}}) \geq 0$. But $\sigma^2_r > \sigma_{r\tilde{r}}$, so $\sigma_{r\tilde{d}} \geq 0$ is sufficient. Under random walk exchange rates $\sigma_{r\tilde{d}} = \sigma_{\tilde{r}\tilde{d}}$. Hence, the sufficient condition becomes $\sigma_{\tilde{r}\tilde{d}} \geq 0$. This is the sufficient condition due to symmetry in the $\eta = 0$ DCP case also.

# G Proof of proposition 4

In the extended model, the firm faces a generic demand curve $Y(p^j_i / q_i)$ where $p^j_i$ is the price in local currency units and $q^i$ is a local demand shifter. Let $\mathcal{S} = (\varepsilon^j, S, w, q, C)$ the vector of all the random variables, and redundantly including the marginal cost in it, as it is also a function of the state variable as well as the currency of credit choice variable.

**Preliminary: The flexible price optimum.** The expression for profits when the price is set in local currency is now:

$$\pi^{LCP}_i(p^j_i, \mathcal{S}) = \left[s_i p^j_i - C\right] Y\left(\frac{p^j_i}{q_i}\right). \tag{A64}$$

Let $p^{F,j}_i(\mathcal{S})$ be the optimal price set by a firm that maximizes this expression. This is the optimal flexible price set by the firm that faces no nominal stickiness. The fact that we express this in local currency, as opposed to any of the alternatives, is irrelevant since the price flexibly adjusts to the exchange rates.

We approximate the model around the point where stochastic variables are at a fixed point equal to their means: $\mathcal{S} = (\bar{\varepsilon}^j, \bar{S}, \bar{w}, \bar{q}, \bar{C})$. We denote with a hat log-linear deviations from this point. It is straightforward to derive (e.g., Arkolakis et al., 2018) that the optimal flexible price is, to the first order:

$$\hat{p}_i^{F,j} = (1-\lambda)\left(\hat{c}^j - \hat{s}_i\right) + \lambda \hat{q}_i \tag{A65}$$

where $\lambda$ depends on the shape of the demand function. For example, if the demand curve follows a Kimball Aggregator, $Y(p_i^j/q_i) = (1 - \vartheta(\ln(p_i^j) - \ln(q^i)))^{\theta/\vartheta}$, as for instance in Klenow and Willis (2016), then: $\lambda = 1 - (1 + \frac{\vartheta}{\theta-1})^{-1}$.

Since $\hat{q}_i$ is common to all firms in that market, this introduces a complementarity in demand. The larger is $\lambda$, the stronger this is.

**Preliminary: the marginal cost function.** The firm produces using a production function $F(x_j, l_j)$, which is homogeneous of degree one and has corresponding marginal cost function $C(\eta^j, \varepsilon^j, S, w, q)$. The approximation point that we used above is therefore defined by: $\bar{C}(\eta^j) = C^j(\eta^j, \bar{\varepsilon}^j, \bar{S}, \bar{w}, \bar{q})$.

To a first approximation around this point, we get:

$$\hat{c}^j(1,.) = \kappa_{1,w} w + \kappa_{1,r} s_r + \kappa_{1,\varepsilon^j} \varepsilon^j \tag{A66}$$

The new parameters are defined as:

$$\kappa_{1,w} = \frac{\partial C}{\bar{W}\partial W}(1, \bar{\varepsilon}^j, \bar{S}, \bar{w}, \bar{q}), \quad \kappa_{1,r} = \frac{\partial C}{\bar{S}_r \partial S_r}(1, \bar{\varepsilon}^j, \bar{S}, \bar{w}, \bar{q}), \quad \kappa_{1,\varepsilon^j} = \frac{\partial C}{\bar{\varepsilon}^j \partial \varepsilon^j}(1, \bar{\varepsilon}^j, \bar{S}, \bar{w}, \bar{q}). \tag{A67}$$

Finally, define $\sigma_c^2$ as the variance of $\hat{c}^j$ and $\sigma_{cx}$ as the relevant covariance with another log-linearized variable $x$.

**Preliminary: LCP vs. PCP.** Recall the definition of the expressions for profits under LCP and PCP, re-written as a ratio of those at the steady state:

$$\pi_i^{LCP}(\hat{p}_i^j, \mathcal{S}) = \left[\exp\{\hat{s}_i + \hat{p}_i^j\} - C^j\right] Y\left(\exp\{\hat{p}_i^j - \hat{q}_i\}\right), \tag{A68}$$

$$\pi_i^{PCP}(\hat{p}_i^j, \mathcal{S}) = \left[\exp\{\hat{s}_i + \hat{p}_i^j\} - C^j\right] Y\left(\exp\{\hat{p}_i^j - \hat{s}_i - \hat{q}_i\right). \tag{A69}$$

We will approximate these about the flexible-price equilibrium, since when there is no uncertainty in the steady state, it is as if prices are flexible. Note however that since $\hat{p}_i^{F,j}$ was written in local-currency units, then it is the approximation point for LCP but for PCP, the point is: $\hat{p}_i^{F,j} - \hat{s}_i$.

From the definition of profit-maximizing prices:

$$\frac{\partial \pi^{PCP}(\hat{p}_i^{F,j} - \hat{s}_i, \mathcal{S})}{\partial \hat{p}_i^{F,j}} = \frac{\partial \pi^{LCP}(\hat{p}_i^{F,j}, \mathcal{S})}{\partial \hat{p}_i^{F,j}} = 0 \tag{A70}$$

Similarly, the second-derivatives will be the same and less than zero at this point. Therefore, to the second-order around the flexible price, we have that:

$$\pi^{PCP}(\hat{p}_i^j; \mathcal{S}) - \pi^{LCP}(\hat{p}_i^j; \mathcal{S}) = \frac{1}{2} \frac{\partial^2 \pi^{LCP}(\hat{p}_i^{F,j}; \mathcal{S})}{\partial \left(\hat{p}_i^{F,j}\right)^2} \left[ \left( \hat{p}_i^j - \hat{s}_i - \hat{p}_i^{F,j}(\mathcal{S}) \right)^2 - \left( \hat{p}_i^j - \hat{p}_i^{F,j}(\mathcal{S}) \right)^2 \right]. \tag{A71}$$

Next, we approximate around the non-stochastic point: $\bar{\mathcal{S}}$. Note that:

$$\frac{\partial^2 \pi^{LCP}(\hat{p}_i^{F,j}; \mathcal{S})}{\partial \left(\hat{p}_i^{F,j}\right)^2} = \frac{\partial^2 \pi^{LCP}(\hat{p}_i^{F,j}; \bar{\mathcal{S}})}{\partial \left(\hat{p}_i^{F,j}\right)^2} + \mathcal{O}(\|\mathcal{S} - \bar{\mathcal{S}}\|) \tag{A72}$$

Therefore, taking expectations of the previous expression one gets:

$$\mathbb{E}\left[\pi^{PCP}(\hat{p}_i^j; \mathcal{S}) - \pi^{LCP}(\hat{p}_i^j; \mathcal{S})\right] \approx \frac{1}{2} \frac{\partial^2 \pi^{LCP}(\hat{p}_i^{F,j}; \bar{\mathcal{S}})}{\partial \left(\hat{p}_i^{F,j}\right)^2} \mathbb{E}\left[ \left( \hat{p}_i^j - \hat{s}_i - \hat{p}_i^{F,j}(\mathcal{S}) \right)^2 - \left( \hat{p}_i^j - \hat{p}_i^{F,j}(\mathcal{S}) \right)^2 \right]. \tag{A73}$$

It follows that the firm will choose PCP over LCP if this expression is negative, or:

$$\mathbb{E}\left( \hat{p}_i^j - \hat{s}_i - \hat{p}_i^{F,j} \right)^2 \leq \mathbb{E}\left( \hat{p}_i^j - \hat{p}_i^{F,j} \right)^2. \tag{A74}$$

Using equation (A65), this becomes:

$$\mathbb{E}\left( (1-\lambda)\left(\hat{c}^j\right) + \lambda \hat{q}_i + \lambda \hat{s}_i \right)^2 \leq \mathbb{E}\left( (1-\lambda)\left(\hat{c}^j - \hat{s}_i\right) + \lambda \hat{q}_i \right)^2. \tag{A75}$$

Expanding the expectations and rearranging gives

$$2\sigma_{ic}(1-\lambda)+2\lambda\sigma_{iq}\leq(1-2\lambda)\sigma_i^2. \tag{A76}$$

We will make use of equation (A76) when comparing RCP to LCP below.

**Proof of proposition 4(a): the $\Omega$ threshold.** The state-specific profits under RCP are:

$$\pi_i^{RCP}(\hat{p}_i^j,\mathcal{S})=\left[\exp\{\hat{s}_r+\hat{p}_i^j\}-C^j\right]Y\left(\exp\{\hat{p}_i^j+\hat{s}_r-\hat{s}_i-\hat{q}_i\}\right). \tag{A77}$$

By similar steps the difference between this expression and the PCP expression is, to second-order:

$$\begin{aligned}&\mathbb{E}\left[\pi^{RCP}(\hat{p}_i^j;\mathcal{S})-\pi^{PCP}(\hat{p}_i^j;\mathcal{S})\right]\approx\\&\frac{1}{2}\frac{\partial^2\pi^{PCP}(\hat{p}_i^{F,j};\bar{\mathcal{S}})}{\partial\left(\hat{p}_i^{F,j}\right)^2}\mathbb{E}\left[\left(\hat{p}_i^{P,j}+\hat{s}_r-\hat{s}_i-\hat{p}_i^{F,j}(\mathcal{S})\right)^2-\left(\hat{p}_i^j-\hat{p}_i^{F,j}(\mathcal{S})\right)^2\right].\end{aligned} \tag{A78}$$

Again combining with equation (A65), this becomes:

$$\mathbb{E}\left((1-\lambda)\hat{c}^j-\hat{s}_r+\lambda\hat{q}_i+\lambda\hat{s}_i\right)^2\leq\mathbb{E}\left((1-\lambda)\hat{c}^j+\lambda\hat{q}_i+\lambda\hat{s}_i\right)^2. \tag{A79}$$

Evaluating the expectations gives:

$$\frac{1}{2}\sigma_r^2\leq(1-\lambda)\sigma_{cr}+\lambda(\sigma_{qr}+\sigma_{ir}). \tag{A80}$$

Now, marginal costs are in equation (A66). Therefore: $\sigma_{cr}=\kappa_{1,r}\sigma_r^2+\kappa_{1,w}\sigma_{rw}$. Therefore, the expression above becomes:

$$\frac{1}{2}\sigma_r^2\leq(1-\lambda)\left(\kappa_{1,r}\sigma_r^2+\kappa_{1,w}\sigma_{rw}\right)+\lambda(\sigma_{qr}+\sigma_{ir})\Leftrightarrow \tag{A81}$$

$$\sigma_{rw}\geq\frac{1}{2(1-\lambda)\kappa_{1,w}}\sigma_r^2-\frac{\lambda}{(1-\lambda)\kappa_{1,w}}(\sigma_{qr}+\sigma_{ir})-\frac{\kappa_{1,r}}{\kappa_{1,w}}\sigma_r^2. \tag{A82}$$

This threshold is just like the one in lemma 1(c). In fact, when $\lambda=0$ and the production function is Cobb-Douglas so $\kappa_{1,r}=\alpha$ and $\kappa_{1,w}=1-\alpha$, then the right-hand side of the expression above simplifies to the $\Omega$ defined in the lemma.

**Proof of proposition 4(a): the $\Phi$ threshold.** Inspecting equation (A77), it is apparent that to compare RCP and LCP it is sufficient to add $\sigma_r^2 - 2(1-\lambda)\sigma_{cr} - 2\lambda(1+\lambda)(\sigma_{qr} + \sigma_{ir})$ to equation (A76). So the condition for choosing RCP over LCP is:

$$\sigma_i^2 \geq \frac{1}{(1-2\lambda)}\left[\sigma_r^2 - 2(1-\lambda)\sigma_{cr} - 2\lambda(1-\lambda)(\sigma_{qr}+\sigma_{ir}) + 2\sigma_{ic}(1-\lambda) + 2\lambda\sigma_{iq}\right]. \quad \text{(A83)}$$

This threshold is just like the one in lemma 1b. Again, when $\lambda = 0$ and the production function is Cobb-Douglas so $\kappa_{1,r} = \alpha$ and $\kappa_{1,w} = 1-\alpha$, then the right-hand side of the expression above simplifies to the $\Phi$ defined in the lemma.

**Proof of proposition 4(b): demand complementarities.** In general, how the degree of demand complementarities affects the choice of RCP versus LCP is ambiguous. However, note that the derivative of the left-hand side of equation (A83) with respect to $\lambda$ is given by

$$\frac{2}{(1-2\lambda)^2}\left[2(\sigma_{cr} - \sigma_{ic}) - 2(1-2\lambda)(\sigma_{qr}+\sigma_{ir}) + 2\sigma_{iq})\right] \quad \text{(A84)}$$

This means that if $\lambda > 1/2$, an increase in $\sigma_{qr}$ makes it more likely the firm will choose RCP over LCP. This proves result (b).

**Proof of proposition 4(c): effect of policy.** The same proof as in the baseline case can be used to show that the profit functions in each market are convex in $\eta^j$ independently of the pricing choice. In turn, recall from appendix C, that the profits of the firm are given by equation (A29), repeated here for convenience:

$$\Pi^j(\eta^j) = \int_{\Delta^{LCP}(\eta^j)} \pi_i^{LCP*}(\eta^j)di + \int_{\Delta^{PCP}(\eta^j)} \pi_i^{PCP*}(\eta^j)di + \int_{\Delta^{RCP}(\eta^j)} \pi_i^{RCP*}(\eta^j)di$$
$$+ \int_{\Delta^{DCP}(\eta^j)} \pi_i^{DCP*}di + \delta_0\pi_0^{RCP*}(\eta^j) + \delta_1\pi_1^{DCP*}(\eta^j)$$

The same proof shows that this is convex in $\eta^j$, so again there will be a bang-bang solution.

Imagine a firm that is currently operating with d-currency credit $\eta^j = 0$, and is considering switching to r-currency credit $\eta^j = 1$. It is feasible for the firm to make that switch but leave the pricing currency decisions unchanged, so the sets $\{\Delta^{LCP}, \Delta^{PCP}, \Delta^{RCP}, \Delta^{DCP}\}$ stay the same. The firm could, of course, do better by re-optimizing pricing. But, it is sufficient, to prove result (c), that the difference

$$\pi_i^{\mathcal{P}*}(1, \varepsilon^j, S, w, q) - \pi_i^{\mathcal{P}*}(0, \varepsilon^j, S, w, q) \quad \text{(A85)}$$

increases following the policy change for all $i$ and all choices of $\mathcal{P} \in \{LCP, PCP, RCP, DCP\}$

Note that $\pi_i^{\mathcal{P}*}(0, \varepsilon^j, S, w, q)$ is independent of $\varepsilon^j$, since if d-currency credit is used, the cost of r-currency credit is irrelevant. Therefore, we only need to show that $\pi_i^{\mathcal{P}*}(1, \varepsilon^j, S, w, q)$ increases. But, since $\tilde{G}^j(\varepsilon^j)$ first order stochastically dominates $G^j(\varepsilon^j)$ and the draw of $\varepsilon^j$ of independent of the other variables, this is always the case.

# H Data Sources and Manipulations

**SWIFT data on cross-border financial messages.**

These data were provided by the SWIFT Institute and last received by us on the 5th of December of 2019. We use SWIFT message types MT 103, MT 202 and MT 400 for the analysis. Our definition of payment corresponds to the sum of MT 103 (Single Customer Credit Transfers) and MT 202 (General Financial Institution Transfers). We consolidate message types MT 103+ and MT 103R into MT 103. We omit message type MT 202COV to prevent the double counting, as covered messages have corresponding MT 103 or MT 202 transactions.

The raw data has the total value of the messages sent and received by any two jurisdictions within SWIFT, broken down by the month that the message was sent or received, the message type, and the currency of the message. The value is converted in USD by SWIFT using the prevailing exchange rates on the day of the transactions. We convert our data into a balanced panel, replacing country-pair, message-type, month observations where no information is recorded into zero for the value of the messages.

We consolidate some jurisdictions within the SWIFT dataset together, such as the UK and its offshore dependencies, or the US and its overseas territories. This is to prevent the grossing up of cross-border transactions (sterling flows between the UK and the channel islands are substantial for example) and to ensure that the cross-sectional units we focus on are truly independent states. The complete list of consolidated jurisdictions is provided in the replication code.

**Trade data.**

We use the IMF direction of trade statistics to measure monthly bilateral goods trade between countries (last accessed on the 16th of September of 2019). Exports are measured as goods value free on board. Imports include the cost of insurance. The data is denominated in USD using prevailing market exchange rates and we consolidate certain jurisdictions in the same manner as the SWIFT data above.

**GDP data.**

We use the April 2019 vintage of the IMF world economic outlook to source cross country GDP data (last accessed on the 23rd of September of 2019). Nominal GDP in USD at market exchange rates is WEO code NGDPD, nominal GDP at PPP exchange rates is WEO code PPPGDP and we convert the later into per capita terms using the country's population (WEO code LP).

**Exchange rate data.**

We use the IMF International Financial Statistics to obtain market exchange rates (last accessed on the 23rd of September of 2019).

**Producer Price Index data.**

We use the IMF International Financial Statistics to obtain monthly producer price indices for the countries in our sample (last accessed on the 9th March of 2020). We compute $\sigma_{rw}$ using the covariance of year on year growth in the PPI versus the RMB exchange rate.

**Distance data.**

Data on distance between countries come from the CEPII GeoDist database described in Mayer and Zignago (2011). We downloaded these data from the CEPII website on 21st October of 2019. We use the location of the capital as location of the country and calculate distance using the great-circle distance method.

**Swap line data.**

The complete dataset on PBoC swap lines is provided in table A1.

**Chinese Investment.**

Data on Chinese fixed investment projects in foreign countries comes from the Chinese Global Investment Tracker compiled by the American Enterprise Institute. We use the Spring 2019 vintage last accessed on the 30th December of 2019. We take the dollar figure

## Table A1: The PBoC's swap lines 2009-2018

| Country | Date of First Agreement (2009 onwards only) | Notional Amount as of First Agreement (RMB millions) |
|---|---|---|
| Albania | 12/09/2013 | 2,000 |
| Argentina | 02/04/2009 | 70,000 |
| Armenia | 25/03/2015 | 1,000 |
| Australia | 22/03/2012 | 200,000 |
| Belarus | 11/03/2009 | 20,000 |
| Brazil | 26/03/2013 | 190,000 |
| Canada | 08/11/2014 | 200,000 |
| Chile | 25/05/2015 | 22,000 |
| ECB | 08/10/2013 | 350,000 |
| Egypt | 06/12/2016 | 18,000 |
| Hong Kong | 20/01/2009 | 200,000 |
| Hungary | 09/09/2013 | 10,000 |
| Iceland | 09/06/2010 | 3,500 |
| Japan | 26/10/2018 | 200,000 |
| Indonesia | 23/03/2009 | 100,000 |
| Kazakhstan | 13/06/2011 | 7,000 |
| Korea, Republic of | 20/04/2009 | 180,000 |
| Malaysia | 08/02/2009 | 80,000 |
| Mongolia | 06/05/2011 | 5,000 |
| Morocco | 11/05/2016 | 10,000 |
| New Zealand | 18/04/2011 | 25,000 |
| Nigeria | 27/04/2018 | 15,000 |
| Pakistan | 23/12/2011 | 10,000 |
| Qatar | 03/11/2014 | 35,000 |
| Russia | 13/10/2014 | 150,000 |
| Serbia | 17/06/2016 | 1,500 |
| Singapore | 23/07/2010 | 150,000 |
| South Africa | 10/04/2015 | 30,000 |
| Sri Lanka | 16/09/2014 | 10,000 |
| Surinam | 18/03/2015 | 1,000 |
| Switzerland | 21/07/2014 | 150,000 |
| Tajikistan | 03/09/2015 | 3,000 |
| Thailand | 22/12/2011 | 70,000 |
| Turkey | 21/02/2012 | 10,000 |
| United Kingdom | 22/06/2013 | 200,000 |
| Ukraine | 26/06/2012 | 15,000 |
| United Arab Emirates | 17/01/2012 | 35,000 |
| Uzbekistan | 19/04/2011 | 700 |

Notes: Records all swap agreements signed between 2009 and 2018, hand collected from PBoC press releases and cross-referenced with partner central banks. Some agreements have lapsed since initiation.

of monthly investment flows recorded in each country and the cumulated since the start of the dataset and express both as a percentage of the country's nominal GDP.

**Membership of the AIIB.**

Membership of the Asian Infrastructure Investment Bank was downloaded directly from this website, last accessed on the 30th December of 2019.

**Chinese Free Trade Agreements.**

Data on the Chinese Free Trade Agreement network was downloaded from the Chinese ministry of commerce (see here, last accessed on the 16th April of 2020). We date free trade agreements from their effective dates. We count ASEAN members as having a FTA starting from when the ASEAN framework was agreed in November 2002.

# Tables

Table 1: Summary Statistics: Main Regression Sample

| | mean | p50 | min | max | sd |
|---|---|---|---|---|---|
| $1(\text{Rpayment}_{i,t} > 0)$ | 0.275 | 0 | 0 | 1 | 0.447 |
| $\text{Rshare}_{i,t}$ | 0.005 | 0 | 0 | 0.942 | 0.034 |
| $\text{SwapLine}_{i,t}$ | 0.118 | 0 | 0 | 1 | 0.322 |
| Goods exports to China (% GDP) | 0.084 | 0.020 | 0 | 0.964 | 0.152 |
| Goods imports from China (% GDP) | 0.122 | 0.011 | 0 | 0.784 | 0.080 |
| Chinese direct investment (% GDP) | 0.017 | 0 | 0 | 24.64 | 25.81 |
| Membership of AIIB | 0.069 | 0 | 0 | 1 | 0.254 |
| Has RMB Clearing Bank | 0.024 | 0 | 0 | 1 | 0.153 |
| Observations | 13192 | | | | |

Table 2: The effect of the swap lines on the prob. the RMB is used

| | No controls (1) | Time & Seasonal f.e. (2) | Incl. Neigh. Share (3) | Incl. China Trade (4) | Incl. China Policy (5) |
|---|---|---|---|---|---|
| $\text{SwapLine}_{i,t}$ | 0.2791*** | 0.1299*** | 0.1229*** | 0.1260*** | 0.1435*** |
| | (0.038) | (0.017) | (0.013) | (0.015) | (0.020) |
| $\text{Neighbour Use}_{i,t}$ | | | 0.0717 | 0.0726 | 0.0855 |
| | | | (0.052) | (0.052) | (0.054) |
| Country f.e. | Yes | No | No | No | No |
| Country×Seasonal f.e. | No | Yes | Yes | Yes | Yes |
| Month f.e. | No | Yes | Yes | Yes | Yes |
| China Trade Controls | No | No | No | Yes | Yes |
| China Policy Controls | No | No | No | No | Yes |
| Observations | 13192 | 13192 | 13192 | 13192 | 13192 |

Driscoll-Kraay standard errors in parentheses, * $p < 0.1$, **,$p < 0.05$, *** $p < 0.01$

*Notes: Estimates of equation 10. Sample covers 136 countries over the period October 2010 to October 2018. LHS is an indicator variable for whether the country sends or receives a payment denominated in RMB in a particular month where payment is defined by SWIFT message types MT 103 and MT 202. The variable of interest is a dummy variable indicating whether the country's central bank, as of month t, has ever signed a swap line agreement with the PBoC. Column (1): includes only country fixed effects and no further controls. Column (2): allows country fixed effects to vary by calendar month to control for country specific seasonal factors and includes month fixed effects to control for common trends. Column (3): as previous, but includes Neighbor* $\text{Use}_{i,t}$ *as an extra control. Column (4): as previous, but includes as extra controls a Chinese FTA dummy and trade flows with China. Column (5): as previous, but includes as extra controls dummies for membership of the AIIB and the presense of an RMB clearing bank and Chinese investment flows into the country.*

Table 3: The effect of the swaplines: state visit IV

| | full sample | |
|---|---|---|
| | Time & Seasonal f.e. (1) | All controls (2) |
| $\text{SwapLine}_{i,t}$ | 0.5063*** | 0.5724** |
| | (0.145) | (0.224) |
| $\text{Neighbor Use}_{i,t}$ | | 0.0337 |
| | | (0.061) |
| Country f.e. | No | No |
| Country×Seasonal f.e. | Yes | Yes |
| Month f.e. | Yes | Yes |
| China Trade Controls | No | Yes |
| China Policy Controls | No | Yes |
| Observations | 13192 | |

Driscoll-Kraay standard errors in parentheses
* $p < 0.1$, **,$p < 0.05$, *** $p < 0.01$

*Notes: Estimates of equation 10 where $SwapLine_{i,t}$ is instrumented with a dummy variable indicating , as of month $t$, whether the country has recieved a state visit from the Chinese premier since the start of the sample. Sample covers 136 countries over the period October 2010 to October 2018. LHS is an indicator variable for whether the country sends or receives a payment denominated in RMB in a particular month where payment is defined by SWIFT message types MT 103 and MT 202. Column (1): includes country fixed effects varying by calendar month to control for country specific seasonal factors and includes month fixed effects to control for common trends. Column (2): as previous, but includes the full set of neighbor, trade and policy controls.*

Table 4: The effect of the swap lines signed by neighbor countries

| | all countries | | ex countries with swapline | |
|---|---|---|---|---|
| | Time & Seasonal f.e. | Control for far countries | Time & Seasonal f.e. | Control for far countries |
| | (1) | (2) | (3) | (4) |
| $\text{SwapLine}_{i,t}$ | 0.0975*** | 0.0527*** | 0.0797*** | 0.0255*** |
| | (0.013) | (0.005) | (0.012) | (0.003) |
| Far Country $\text{Use}_{i,t}$ | | -21.8582*** | | -19.4789*** |
| | | (0.670) | | (0.383) |
| Country f.e. | No | No | Yes | No |
| Country×Seasonal f.e. | Yes | Yes | No | Yes |
| Month f.e. | Yes | Yes | No | Yes |
| Observations | 13192 | 13192 | 13192 | 13192 |

Driscoll-Kraay standard errors in parentheses, * $p < 0.1$, **,$p < 0.05$, *** $p < 0.01$

*Notes: Estimates of equation 10 where the LHS is replaced by Neighbor $\text{Use}_{i,t}$. Sample covers 136 countries over the period October 2010 to October 2018. The variable of interest is a dummy variable indicating whether the country's central bank, as of month $t$, has ever signed a swap line agreement with the PBoC. Column (1): includes country fixed effects varying by calendar month to control for country specific seasonal factors and includes month fixed effects to control for common trends. Column (2): as previous, but includes Far Country $\text{Use}_{i,t}$ as a control. Column (3)-(4): repeats Columns (1)-(2) but excludes countries that have ever signed a swap agreement with the PBoC from the Neighbor $\text{Use}_{i,t}$ variable*

Table 5: The effect of the swaplines: sorting on correlation

| | all payments | | all payments w/controls | | payments rec'd | |
|---|---|---|---|---|---|---|
| | low corr. | high corr. | low corr. | high corr. | low corr. | high corr. |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| $\text{SwapLine}_{i,t}$ | -0.1190*** | 0.1065*** | -0.0494** | 0.1129*** | -0.1017*** | 0.1621*** |
| | (0.018) | (0.028) | (0.019) | (0.032) | (0.024) | (0.044) |
| $\text{Neighbor Use}_{i,t}$ | | | 0.2654** | | 0.1675 | |
| | | | (0.108) | | (0.102) | |
| Country f.e. | Yes | | No | | No | |
| Country×Seasonal f.e. | Yes | | Yes | | Yes | |
| Month f.e. | Yes | | Yes | | Yes | |
| China Trade Controls | No | | Yes | | Yes | |
| China Policy Controls | No | | Yes | | Yes | |
| Observations | 4462 | | 4462 | | 4462 | |

Driscoll-Kraay standard errors in parentheses, * $p < 0.1$, **,$p < 0.05$, *** $p < 0.01$

*Notes: Estimates of equation 10 with $\text{SwapLine}_{i,t}$ interacted with an indicator variable for whether the correlation between country i's RMB exchange rate and its PPI inflation rate is above or below the sample median. Correlations are computed in terms of 12 month growth rates over the sample. Limited availability of PPI data means that the sample covers 42 countries over the period October 2010 to October 2018. LHS is an indicator variable for whether the country sends or receives a payment denominated in RMB in a particular month where payment is defined by SWIFT message types MT 103 and MT 202. Column (1)-(2): includes country fixed effects varying by calendar month to control for country specific seasonal factors and includes month fixed effects to control for common trends. Column (3)-(4): as previous, but includes the full set of neighbor, trade and policy controls. Column (5)-(6): as previous, but redefines LHS variable to only consider payments received.*

Table 6: The effect of the swap lines: exclude payments to and from China

| | No controls (1) | Time & Seasonal f.e. (2) | Incl. Neigh. Share (3) | Incl. China Trade (4) | Incl. China Policy (5) |
|---|---|---|---|---|---|
| $\text{SwapLine}_{i,t}$ | 0.2382*** | 0.1173*** | 0.1066*** | 0.1097*** | 0.1072*** |
| | (0.045) | (0.034) | (0.029) | (0.029) | (0.027) |
| Neighbor $\text{Use}_{i,t}$ | | | 0.1098** | 0.1112** | 0.1075** |
| | | | (0.051) | (0.050) | (0.049) |
| Country f.e. | Yes | No | No | No | No |
| Country×Seasonal f.e. | No | Yes | Yes | Yes | Yes |
| Month f.e. | No | Yes | Yes | Yes | Yes |
| China Trade Controls | No | No | No | Yes | Yes |
| China Policy Controls | No | No | No | No | Yes |
| Observations | 13192 | 13192 | 13192 | 13192 | 13192 |

Driscoll-Kraay standard errors in parentheses, * $p < 0.1$, **,$p < 0.05$, *** $p < 0.01$

*Notes: Estimates of equation 10. LHS is an indicator variable for whether the country sends or receives a payment denominated in RMB in a particular month where payment is defined by SWIFT message types MT 103 and MT 202. This excludes payments to and from China (including Hong Kong and Macau). Sample covers 136 countries over the period October 2010 to October 2018. The variable of interest is a dummy variable indicating whether the country's central bank, as of month $t$, has ever signed a swap line agreement with the PBoC. Column (1): includes only country fixed effects and no further controls. Column (2): allows country fixed effects to vary by calendar month to control for country specific seasonal factors and includes month fixed effects to control for common trends. Column (3): as previous, but includes Neighbor $\text{Use}_{i,t}$ as an extra control. Column (4): as previous, but includes as extra controls a Chinese FTA dummy and trade flows with China. Column (5): as previous, but includes as extra controls dummies for membership of the AIIB and the presense of an RMB clearing bank and Chinese investment flows into the country.*

Table 7: The effect of the swaplines: different payment types

| | payments rec'd | | payments sent | | trade payments (MT 400) | |
|---|---|---|---|---|---|---|
| | f.e. only | all controls | f.e. only | all controls | f.e. only | all controls |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| $\text{SwapLine}_{i,t}$ | 0.1299*** | 0.1435*** | 0.1310*** | 0.1448*** | 0.0792*** | 0.0685* |
| | (0.017) | (0.020) | (0.017) | (0.021) | (0.019) | (0.037) |
| $\text{Neighbour}_{i,t}$ | | 0.0855 | | 0.0859 | | -0.0073 |
| | | (0.054) | | (0.054) | | (0.016) |
| Country f.e. | No | No | No | No | No | No |
| Country×Seasonal f.e. | Yes | Yes | Yes | Yes | Yes | Yes |
| Month f.e. | Yes | Yes | Yes | Yes | Yes | Yes |
| China Trade Controls | No | Yes | No | Yes | No | Yes |
| China Policy Controls | No | Yes | No | Yes | No | Yes |
| Observations | 13192 | | 13192 | | 10802 | |

Driscoll-Kraay standard errors in parentheses, * $p < 0.1$, **,$p < 0.05$, *** $p < 0.01$

*Notes: Estimates of equation 10. Sample covers 136 countries over the period October 2010 to October 2018. Odd columns: includes country fixed effects varying by calendar month to control for country specific seasonal factors and includes month fixed effects to control for common trends. Even columns: as odd columns, but includes the full set of neighbor, trade and policy controls. Columns (1)-(2): LHS is an indicator variable for whether the country receives a payment denominated in RMB in a particular month where payment is defined by SWIFT message types MT 103 and MT 202. Columns (3)-(4): LHS is an indicator variable for whether the country sends a payment denominated in RMB in a particular month where payment is defined by SWIFT message types MT 103 and MT 202. Columns (5)-(6): LHS is an indicator variable for whether the country sends or receives an advice of payment denominated in RMB in a particular month where payment is defined by SWIFT message type MT 400.*

Table 8: The effect of the swap lines on share of RMB in payments

| | No controls (1) | Time & Seasonal f.e. (2) | Incl. Neigh. Share (3) | Incl. China Trade (4) | Incl. China Policy (5) |
|---|---|---|---|---|---|
| SwapLine Agreement$_{i,t}$ | 0.0063** | 0.0038* | 0.0036* | 0.0038* | 0.0034 |
| | (0.003) | (0.002) | (0.002) | (0.002) | (0.002) |
| Neighbour Use$_{i,t}$ | | | 0.0021 | 0.0021 | 0.0018 |
| | | | (0.002) | (0.002) | (0.002) |
| Country f.e. | Yes | No | No | No | No |
| Country×Seasonal f.e. | No | Yes | Yes | Yes | Yes |
| Month f.e. | No | Yes | Yes | Yes | Yes |
| China Trade Controls | No | No | No | Yes | Yes |
| China Policy Controls | No | No | No | No | Yes |
| Observations | 13192 | 13192 | 13192 | 13192 | 13192 |
| Driscoll-Kraay standard errors in parentheses, * $p < 0.1$, **,$p < 0.05$, *** $p < 0.01$ | | | | | |

*Notes: Estimates of equation 10 where the LHS is replaced by Rshare$_{i,t}$, the proportion of payments sent or received by country i in month t denominated in RMB where payment is defined by SWIFT message types MT 103 and MT 202. Sample covers 136 countries over the period October 2010 to October 2018.The variable of interest is a dummy variable indicating whether the country's central bank, as of month t, has ever signed a swap line agreement with the PBoC. Column (1): includes only country fixed effects and no further controls. Column (2): allows country fixed effects to vary by calendar month to control for country specific seasonal factors and includes month fixed effects to control for common trends. Column (3): as previous, but includes Neighbor Use$_{i,t}$ as an extra control. Column (4): as previous, but includes as extra controls a Chinese FTA dummy and trade flows with China. Column (5): as previous, but includes as extra controls dummies for membership of the AIIB and the presense of an RMB clearing bank and Chinese investment flows into the country.*

Table 9: Persistence of the effect of the swap lines

| | $1(\text{Rpayment}_{i,t} > 0)$ | | $\text{Rshare}_{i,t}$ | |
|---|---|---|---|---|
| | Time & Seasonal f.e. | All Controls | Time & Seasonal f.e. | All Controls |
| | (1) | (2) | (3) | (4) |
| SwapLine: first 12 months$_{i,t}$ | 0.1114*** | 0.1228*** | -0.0019 | -0.0018 |
| | (0.031) | (0.031) | (0.003) | (0.003) |
| SwapLine: after 12 months$_{i,t}$ | 0.1378*** | 0.1536*** | 0.0062*** | 0.0060** |
| | (0.016) | (0.019) | (0.002) | (0.003) |
| Neighbor Use$_{i,t}$ | | 0.0836 | | 0.0012 |
| | | (0.054) | | (0.002) |
| Country f.e. | No | No | No | No |
| Country×Seasonal f.e. | Yes | Yes | Yes | Yes |
| Month f.e. | Yes | Yes | Yes | Yes |
| China Trade Controls | No | Yes | No | Yes |
| China Policy Controls | No | Yes | No | Yes |
| Observations | 13192 | 13192 | 13192 | 13192 |

Driscoll-Kraay standard errors in parentheses, * $p < 0.1$, **,$p < 0.05$, *** $p < 0.01$

*Notes: Estimates of equation 10 with SwapLine$_{i,t}$ interacted with an indicator variable for whether the swap line agreement was signed more or less than 12 months ago. Limited availability of PPI data means that the sample covers 42 countries over the period October 2010 to October 2018. Column (1)-(2): LHS is an indicator variable for whether the country sends or receives a payment denominated in RMB in a particular month where payment is defined by SWIFT message types MT 103 and MT 202. Column (3)-(4): LHS is replaced by Rshare$_{i,t}$, the proportion of payments sent or received by country i in month t denominated in RMB where payment is defined by SWIFT message types MT 103 and MT 202. Odd Columns: includes country fixed effects varying by calendar month to control for country specific seasonal factors and includes month fixed effects to control for common trends. Even Columns: as odd columns, but includes the full set of neighbor, trade and policy controls.*