

# Jumpstarting an International Currency\*

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## **Abstract**

While the USD dominates cross-border transactions today, a few other currencies are also used internationally. This paper shows that central bank policies that reduce the volatility of borrowing costs for foreign firms in domestic currency can trigger a jump-start of the currency's international status, because choices of the currency of working capital and sales invoicing complement each other. Empirically, the creation of 38 swap lines by the People's Bank of China between 2009 and 2018 supports this theoretical claim. Signing a swap line with a country increased the probability that it would use the RMB at all by 14%, and its share in the country's payments by 1.3 percentage points.

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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 today are the euro, the yen, pound sterling, the Swiss franc, 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 modeled the complementarities and scale effects that make one currency become dominant, and 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.<sup>1</sup> But before a currency can become dominant, it has to become international. Fewer studies have investigated how a currency achieves that status, and almost none have asked which government policies assist (or hinder) that jump-start. Why have the euro, yen, sterling and franc survived for decades in international usage in spite of the dollar dominance? Why did the yuan join this group in the last decade when the Brazilian real, or the Indian rupee, have not done so? Did the deliberate policies of the People's Bank of China a decade ago play a role and if so how large was it? This paper investigates these questions.

It makes two contributions. First, it provides an empirical analysis of 38 People's Bank of China (PBoC) swap lines signed between 2009 and 2018 providing RMB lending of last resort to foreign firms through banks. These recent central bank policies are interesting in their own right, in light of their rapid growth. We describe their properties, characterize their growth, and show that their predicted direct effect is to cut the right tail of the distribution of borrowing costs in RMB. Because these swap lines were signed with different countries at different times this creates variation with which to establish their causal effects. 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. These data have the advantage of covering many countries over a decade, so we can exploit the cross-country variation to estimate the consequences of signing the swap lines.

Our main finding is that, following the introduction of a swap line, there was significant growth in the use of the RMB at the extensive margin. Comparing countries that signed a RMB swap line with those that did not, while controlling for a series of con-

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<sup>1</sup>See Prasad (2015), Gopinath (2015), Eichengreen, Mehl and Chitu (2017), Ilzetzki, Reinhart and Rogoff (2020) among many others.

founding factors, we find that a swap line raises the probability that the country uses the RMB for international payments by approximately 14%, and the share of the RMB in payments goes from approximately 0 to 1.3%. At the same time, we also find that borrowing costs in RMB fall by 0.8 percentage points.

Digging deeper, we show that if a country signs a swap line, then its neighbors' use of the RMB increases by 10%, even if they do not have a swap line themselves, confirming the spillovers of these policies. Most of the effect of the swap lines on using the RMB happens within 12 months of the signature, confirming a jump-start, and persists long after the agreement is first signed. These effects are not accounted for by increasing trade with China or by other policies between China and the country that signed the swap line. Moreover, they apply to payments using the RMB that are not to, or from, China itself. Instrumenting the swap line date with the plausibly exogenous date at which there was a Chinese state visit to the country further supports the causal link from the swap line to the RMB jump-start.

The second contribution of the paper is a theoretical framework to make sense of these findings. We put forward a model of a small open economy populated by import-export firms that choose the currency in which to invoice their goods in their export markets *and* the currency of denomination of their trade credit for imported inputs. While the literature has so far focussed on the currency of sales and on the assets of economic agents, we focus on the currency of firms' liabilities. We do so to be able to link the effect of the central bank policies on borrowing costs for firms. A second feature of the model is that there is an alternative dominant currency so that, before the policy intervention, the rising currency is not used at all. This allows us to study the jump start that we see in the data.

A key feature in our model is that firms face uncertainty over the interest rate on trade credit. By cutting the right tail of the distribution of borrowing costs a swap line makes trade credit in a particular currency more attractive. Sticky prices generate a complementarity between the currency of liabilities and the currency of invoicing. The net result is a threshold on the distribution of borrowing costs that, when cleared, leads a currency to jump-start into international usage. The theory predicts that the RMB was close enough to the key threshold that when the swap line shifted the distribution of borrowing costs, it triggered a jump start in RMB usage that matches the extensive margin effects that we estimated in the data.

The theory further predicts that the threshold to jump-start a currency's use in a particular economy depends on the size of the currency's domestic market, the importance

of imported inputs, the relative variances of bilateral exchange rates, and the covariance of its exchange rate with local input costs. To validate the model we test these predictions in the data. We find that the introduction of a swap line with the PBoC has a larger affect on RMB usage in countries that have a higher trade share with China, that import more intermediate goods, whose export industries require more working capital, and whose domestic prices have a higher covariance with the RMB exchange rate.

We conclude by noting the strong parallels between the rise of the RMB and the rise of the USD one century earlier. Our results suggest that, with current policies, the RMB is still quite far from threatening the hegemony of the USD.

**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 jump-start the international use of a currency. In the context of the Federal Reserve (Fed), it has been difficult to separate the effect of the policies from other factors, like the effect of World War I on the London market, or the increasing size of the US economy. We provide an analogy with the PBoC, and use its swap lines as a way to test for the effects of these policies. 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.

A large analytical literature studies the choice of international currencies, mostly focussing on why the USD became dominant and what are its consequences (Maggiori, 2017, Gourinchas, Rey and Sauzet, 2019, Gopinath et al., 2020, Chahrour and Valchev, 2021). We contribute to this literature by analyzing the early stages of adoption, 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.

The literature on currency adoption has focussed on the choice of currency invoicing. It has emphasized a firm's desire to match the currency exposure of costs and revenues separately in each market (Engel, 2006, Gopinath, Itskhoki and Rigobon, 2010), the complementarity across firms in the same market that arises from the demand for goods (Bacchetta and van Wincoop, 2005, Goldberg and Tille, 2008), and the complementarity between exports and imports (Mukhin, 2022, Chung, 2016). We focus instead on the currency at which the firm borrows, and the complementarity with the currency of invoicing.<sup>2</sup>

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<sup>2</sup>Why don't firms hedge currency mismatches with forward contracts, whether the mismatch in our

Closer 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 (2022) propose that the dominance of the USD 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. Still on the USD, Drenik and Perez (2021) also introduce a working capital channel, but their focus is on the use of the international currency domestically rather than for cross-border payments. Finally, Gopinath and Stein (2020) like us 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. There are no RMB deposits in almost any of the countries in our sample, so their theory cannot be used to explain our data (and this is also the case for the other international currencies, with the exception of the USD).

Empirically, recent 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, 2021, Amiti, Itskhohi and Konings, 2022), while other work looks at the denomination of financial assets (Maggiori, Neiman and Schreger, 2019). Our data is on payments, rather than invoicing, so it has a broader scope. Moreover, 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, so we can address macro consequences. Closer to our model while using firm-level data, Salomao and Varela (2021) characterizes which Hungarian firms borrow in foreign currency; their findings support the mechanisms guiding the choices of the firms in our model.

Finally, the growing literature studying swap lines (Bahaj and Reis, 2022*b,c*) has focussed mostly on the swap lines established by the Federal Reserve or by the ECB. The features and aims of the USD swap lines are quite different as they: (i) have 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

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model, or the others that dominate the literature? Existing forward contracts pre-specify the quantities hedged ex ante. The ex post risk on how much the firm needs to borrow in working capital, and how much revenue it receives in sales, can therefore not be insured against at the margin using existing forward contracts.

funding needs of foreign banks, as opposed to trade credit and working capital, and (iv) 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.<sup>3</sup> While the RMB's swap lines are different, they are no less economically important: their notional limit of approximately RMB 3tr is comparable to the USD 500bn of peak drawings from the Fed's swap line.

The rest of the paper is organized as follows. Section 2 describes the data, explains how the PBoC swap lines work, and presents the facts on the rise of the RMB as an international currency. It shows the key role of the extensive margin in this growth, consistent with the crossing of thresholds for adoption. Section 3 estimates the effect of signing a swap line on the use of the RMB and on borrowing costs in RMB. Section 4 digs deeper into causality, by showing the effects are not driven by trade with China or by pre-trends, and by using alternative identification strategies based on neighbouring countries' choices and the timing of state visits as an instrument. Sections 5 and 6 make sense of these estimates by presenting the core model and deriving its predictions on the choice of currency of borrowing and its thresholds, how a swap line jump-starts its use. Section 7 theoretically and empirically studies which country features make the jump-start more likely. Section 8 concludes.

## **2 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 A of the appendix.

### **2.1 The PBoC swap lines**

An RMB swap line is an agreement between the PBoC and a foreign central bank enabling it to borrow RMB with the goal of stabilizing the cost of RMB-denominated credit in the foreign currency. The typical agreement is for a fixed duration, usually setting out a 2- or

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<sup>3</sup>See Zhou (2017) for an official PBoC statement on the aims of the swap facilities; explicitly mentioned is currency internationalization and the stabilization of markets for trade credit.

3-year period where the foreign central bank can choose to activate the swap line. So far, these agreements have tended to be renewed.

### 2.1.1 How the RMB swap lines work

The contract works as follows (see Bahaj and Reis, 2022c, for more details). 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 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, so its own currency never enters circulation, and pays back to the PBoC the RMB borrowed plus a pre-agreed interest rate.<sup>4</sup> Since no currency gets exchanged in the spot market, and the interest rate is fixed, the swap line has (sovereign) credit risk for the PBoC, but, outside of default, no exchange-rate risk nor interest-rate risk for either party.

With this agreement in place, a commercial bank that provides credit in RMB to a firm in the foreign country always has the option to go to its central bank to obtain the RMB paying the swap line interest rate. The foreign central bank typically distributes the RMB via a collateralized loan to its commercial banks. In some countries, like Singapore and Korea, there are standing RMB liquidity facilities that are financed by the swap line, but other countries have ad hoc arrangements. In this set up, the foreign central bank monitors the bank and its trade credits, and bears the private credit risk associated with the loans to the commercial banks.

Even if no one uses the swap line most of the time, their presence gives firms the certainty that the interest rate charged for trade credit in RMB will not exceed the swap line rate. Like other central bank lending programs, swap lines put a ceiling on interest rates thereby reducing the interest rate risk faced by commercial banks (and by extension their customers) in dealing in RMB.<sup>5</sup> Essentially, the lines provide insurance against excessively high borrowing costs.

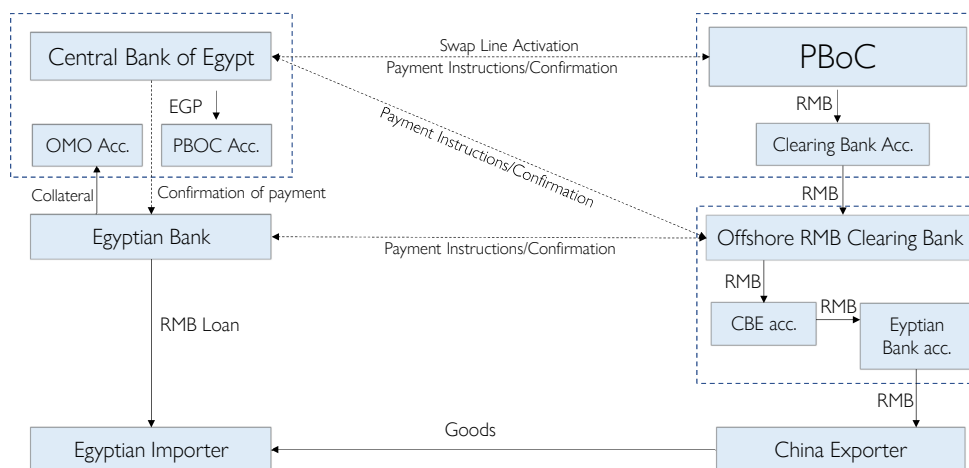
Figure 1 is an illustration of the financial flows associated with swap line financed trade credit based on the example of an Egyptian importer buying goods from a Chinese

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<sup>4</sup>If the foreign central bank defaults on repaying the RMB, then the PBoC can lay claim to the deposit foreign currency to recoup the RMB in the spot market. However, the value and convertibility of the deposit when the central bank is in default will likely be limited.

<sup>5</sup>See Bahaj and Reis (2022a) for further details on the operation of central bank swap lines, and evidence that this ceiling is quite effective.

Figure 1: Sketch of the flows associated with a swap line transaction



exporter. One operational feature of the PBoC’s swap lines arises due to capital controls in China: the RMB is exchanged through an RMB clearing bank either locally (if the country has one), in Hong Kong, or in another offshore RMB centre. The foreign central bank will have an account with the clearing bank, which itself has an account at the PBoC backing it.<sup>6</sup> The figure illustrates that a necessary condition for the swap line to be effective in the first place is that the correspondent banking relationships required for international RMB payments exist. Other steps taken by the PBoC to internationalize the RMB, including establishing the offshore RMB (CNH) market, the trade settlement scheme of 2009, and the international network of clearing banks, are not country specific, and have developed the financial plumbing of the CNH offshore network to any country in the world.

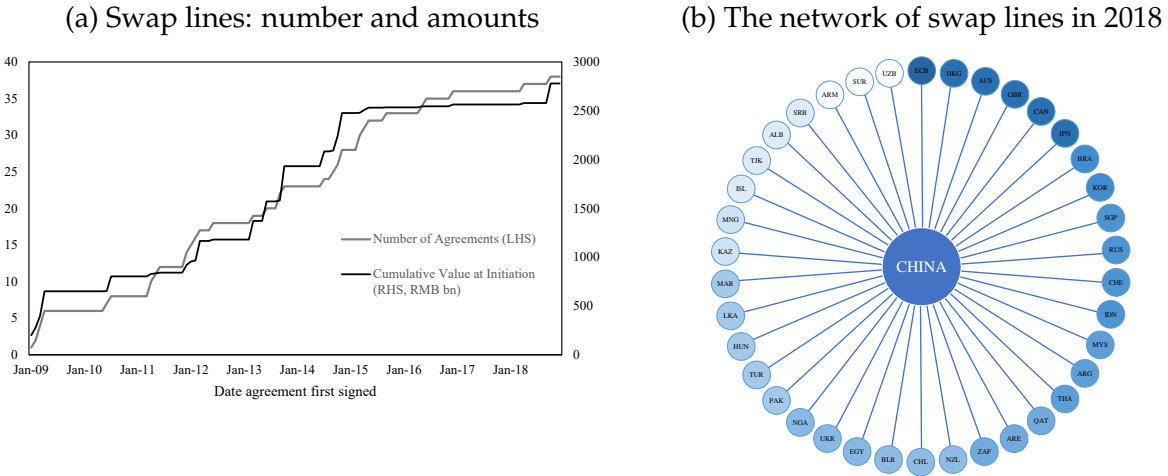
### 2.1.2 The RMB network of swap lines

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 news releases and then cross checked with the foreign central bank’s communications. We complemented it with

<sup>6</sup>In this example, both the Central Bank of Egypt and the Egyptian commercial bank have the same RMB clearing bank acting as as correspondent. This does not need to be the case and there could be further flows within the RMB payment system.



Figure 2: The PBoC swap lines



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 in our dataset. 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  $t$ . The swap line agreements sometimes lapse but are almost always renewed, occasionally with a gap of a few months. As a result, 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 its insurance aspect remains. Hence,  $\text{SwapLine}_{i,t}$  is a binary treatment variable with staggered adoption.

Figure 2 shows the evolution of the number of outstanding swap lines and the sum of their notional limits. The trend is upward sloping. 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. 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 committed amount. Table A1 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. Likewise, countries with large trade or investment relations with China have a swap line. But, beyond these, there are many other swap lines in place without an obvious pattern

driven by economic fundamentals, which were likely driven by the rush to show progress on this political endeavor. This political goal also means that the the timing in which they were signed is not clearly linked to economic fundamentals.

### 2.1.3 Usage of the RMB swap lines

The PBoC does not disclose data on the bilateral usage of the lines nor the interest rate charged (although anecdotes suggest these are above typical market rates, in line with lines capping market rates). The China Monetary Policy report contains information on end of year outstanding balance aggregated across all counterparties: the amount has fluctuated between \$5bn and \$10bn over the course of 2014-2020 (Perks et al., 2021). The time series is short but the year-end balances for the PBoC exceeded the equivalent aggregate drawings from the Federal Reserve's swap lines over the course of 2014-2019. 2020 is an exception: at year end, the Fed provided \$17bn of swap line loans compared to \$8bn for the PBoC. Given the potential maturity of the lines and their role as a back stop, there is likely to be significant fluctuations within year for both central banks. Indeed, the outstanding balance on the Federal Reserve's swap lines peaked at \$450bn in May 2020. Drawings of an equivalent order of magnitude from the PBoC seem highly unlikely as they would be detectable from other sources.

In terms of the counterparties, in a non-exhaustive exercise, McDowell (2019) reports instances of the PBoC swap line usage across 9 different countries based on direct enquiries to the borrowing central central banks. The funds were mainly 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. Perks et al. (2021) additionally report Nigeria borrowed from its line for trade settlement purposes in 2018-19.

As we argued above, the swap line does not need to be frequently used to generate effects. The line's existence insures trading firms against fluctuations in borrowing costs thereby altering incentives even if that insurance is never called upon.<sup>7</sup>

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<sup>7</sup>Evidence of the insurance role of the lines exists elsewhere in the literature. Albrizio, Kataryniuk and Molina (2021) document that the introduction of EUR liquidity lines by the ECB had a significant impact offshore EUR funding costs despite the lines' rare use.

## 2.2 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. In short, they correspond to the dashed lines in figure 1.

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. Volumes are small and SWIFT messages are relied upon for the purpose of communicating with the system (see Deutsche Bank, 2015).

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 is balanced and 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 types MT 400, which is an advice of payment, and MT 700, which confirms the issuance of a letter of credit.<sup>8</sup> These message types arise directly from trade (the actual payments backing MT 400 and MT 700 are recorded separately in SWIFT as message types MT 202 or MT 103). However, not every payment for international trade involves an MT 400 or MT 700 and SWIFT has less complete coverage of these messages.

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

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<sup>8</sup>Specifically, an MT400 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. An MT 700 is a message a bank acting on behalf of an importer to a bank acting on behalf of the exporter that it will make payment to the exporter once required documents are supplied, typically upon receipt of proof of shipping.

Figure 3: RMB share in global payments (and swap lines)

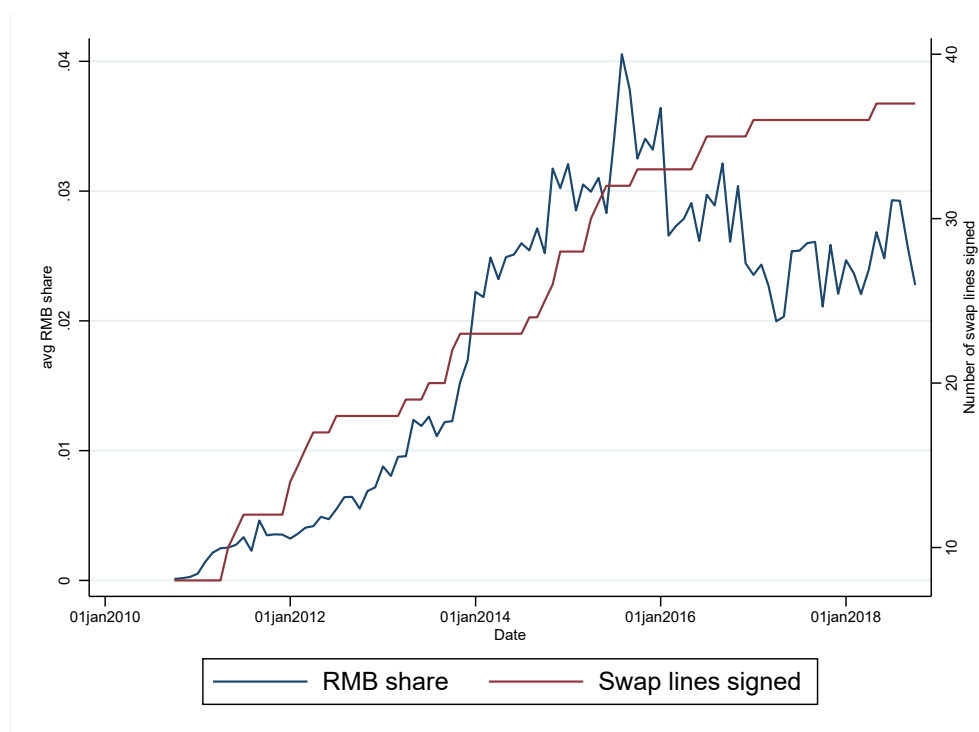


figure 3 (together with the number of swap lines). The upward trend in the use of the RMB since the PBoC started its internationalization strategy is clearly visible, although, as with the number of swap lines growth, has leveled off in recent years.

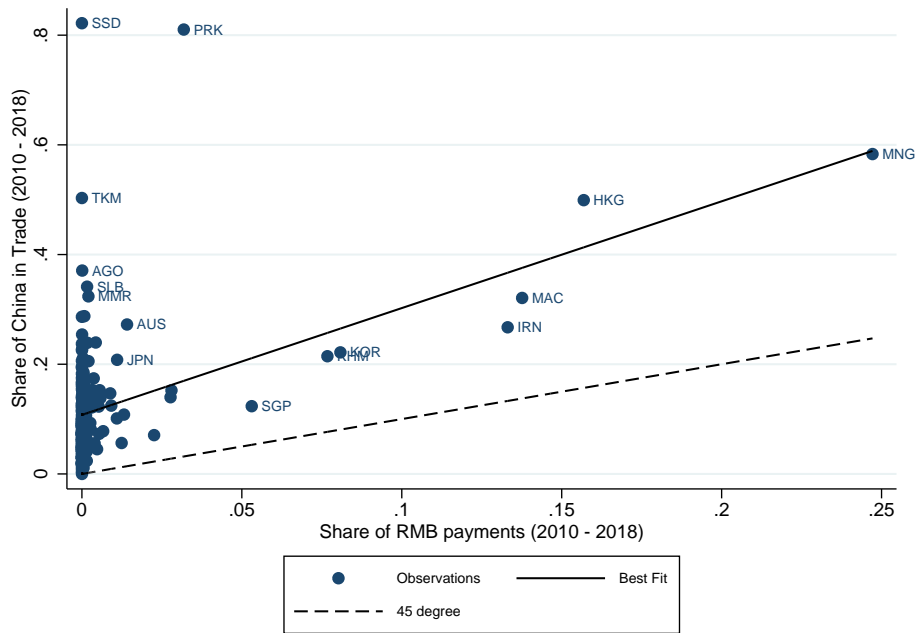
### 2.3 A first look at the data: zeros and the extensive margin

Figure 4 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 majority of countries in the sample though, the use of the RMB at a monthly frequency is close to, or exactly, zero.<sup>9</sup>

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,  $1(\text{Rpayment}_{i,t} >$

<sup>9</sup>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 4: RMB payments per country vs. trade with China



0). A first look at the data suggests that the effect of policy should show up along this extensive margin. We will also look at the impact of policy on the share of cross border payments in RMB,  $Rshare_{i,t}$ .

## 2.4 Sample selection

Developed economies have sophisticated financial sectors 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 if 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. Because of this, we focus on smaller, less developed countries that are reliant on foreign currency credit for trade financing.

Figure 4 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.<sup>10</sup>

Table 1 presents summary statistics for the different variables in our sample. This accounts for the selection criteria detailed in the previous paragraph. For methodological reasons, described below, observations on the four remaining countries had a swap line prior to the start of the sample are also excluded. This leaves us with 12,804 observations on 132 countries, of which 21 are treated during the sample period.

### 3 The empirical effect of the swap lines

Figure 5 plots the mean (left panel) and median (right panel) 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.<sup>11</sup>

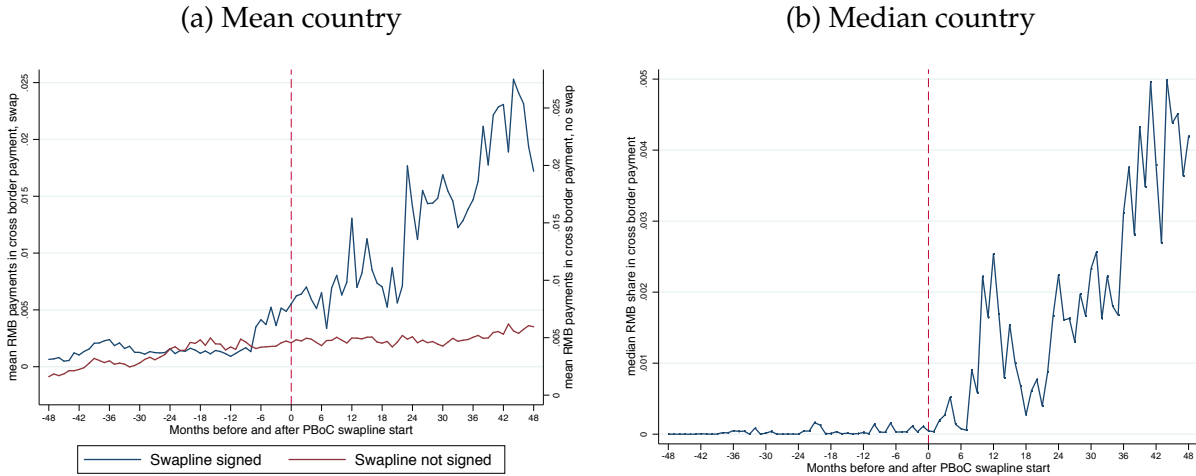
A few conclusions stand out. First, the typical country that signed a swap line made little use of the RMB before the policy took effect. Afterwards, the RMB starts being used and the effect grows over time and persists. Second, a year prior to signing the agreement, the countries used the RMB at similar rates to other countries. Third, there is some evidence of anticipation in that usage does start to increase for the mean country a few months prior to the announcement. The negotiations around a swap agreement are not completely secret and some official announcements are made in the build up to the

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<sup>10</sup>See appendix table A3 for results relaxing this sample selection criteria. 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.

<sup>11</sup>To produce the mean of the countries where a swap line was not signed, we take each country that does sign a swap line, and then take the mean of the countries that never sign a swap agreement in our sample at the same point in time, as well as a second mean of this series across the swap line countries. The median RMB usage for countries that have not signed a swap line is nil for all time periods.

Figure 5: RMB payments share after a swap line is signed



agreement being signed. Considering the role of the facilities as an insurance mechanism, it is not surprising that behavior starts to change even before the agreement is finalized. Fourth, for the median country, prior to an agreement being signed, usage was often zero and there is less evidence of anticipation.

Figure 5 suggests that the swap lines trigger a jump-start of the RMB as an international currency adopted for payments. The rest of this section investigates whether this effect is statistically significant, whether it may be the result of covariates and endogeneity bias, and whether it is working through a change in the borrowing costs that the swap line directly induces.

### 3.1 Baseline estimates: difference in differences

A potential concern in the empirical investigation of swap lines is that the agreements are entered into for endogenous reasons. Anecdotally, it appears that the timing of the agreements were primarily the result of political forces in China and the counter-party. But, it is possible that the RMB usage in a given country increases due to some other factor besides the new policy, which coincides with the country signing a swap line with the PBoC. 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.

To the extent that countries are relatively homogeneous, then time fixed effects  $\tau_t$  can

control for common trends in the adoption of the RMB and the expansion of the swap lines. Country fixed effects  $\zeta_i$  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 combination of fixed effects leads to a panel specification of a linear probability regression:

$$1(\text{Rpayment}_{i,t} > 0) = \zeta_i + \tau_t + \beta \times \text{SwapLine}_{i,t} + \gamma \times \text{Controls}_{i,t} + \text{error}_{i,t}, \quad (1)$$

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 6 is that  $\beta > 0$ .

Equation (1) has the interpretation of a difference-in-differences specification with a staggered, absorbing, binary treatment. The recent literature (see de Chaisemartin and D’Haultfoeuille, 2022, for a survey) has emphasized that estimating such a specification using OLS and fixed effects can bias the estimate of  $\beta$  if the average treatment effect is heterogenous across either countries or time. Another feature of our setting is that the number of countries that sign a swap agreement is relatively small. Therefore, there is a large number of never-treated countries in the sample. Sun and Abraham (2021) propose a simple linear estimator for a difference-in-differences model with staggered adoption that corrects for the bias using the never-treated as the control group, and excluding the always treated. We use their methodology in our baseline setting.<sup>12</sup>

The first two columns of table 2 report the baseline estimates. The first column has no time fixed effects, and the estimate of  $\beta$  is 29%. The second column includes time fixed effects and allows for country-level seasonal factors. This specification compares the RMB usage of the same country before and after signing a swap agreement relative to the usage of the RMB to a country in the sample that never signs an agreement. 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. The availability of swap lines increases the probability that a country uses the RMB by 14%. The effect is large and supports the prediction of the theory.

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<sup>12</sup>In appendix B, we show that these results are very similar when we conduct the estimation using a two-way fixed effects estimator rather than the Sun and Abraham (2021) procedure (see table A2). This suggests that the bias that arises from the heterogeneity in treatment effects is small.



### 3.2 Endogeneity and covariates as controls

There may be 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 1,000km 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  $i$ .<sup>13</sup> The control variable that measures the share of RMB used by country  $i$ 's neighbors is:

$$\text{Neighbor Use}_{i,t} = \frac{1}{|\mathcal{N}_i|} \sum_{j \in \mathcal{N}_i} 1(\text{Rpayment}_{j,t} > 0). \quad (2)$$

A related issue to neighbor usage is that signing a swap agreement can spill over across borders. If an individual country signs an agreement and starts pricing trade in RMB then nearby countries that trade with it may also start using the currency. Such spillovers are inconsistent with a null that the swap line has no effect but they still represent a violation of the stable unit treatment value assumption (SUTVA) which can bias any non-zero effect in arbitrary directions. Controlling for  $\text{Neighbor Use}_{i,t}$ , thereby hold RMB usage of neighbors fixed, is a partial way of dealing with spillovers. In section 4.3, we set up a formal spillover model to dig further into how a swap line affects RMB use in neighboring countries.

Another source of endogeneity may stem from country-specific changes in the relationship with China. For instance, a swap line may be signed around the same time as a trade agreement is reached, 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. It is worth noting however, that we show in section 4.3 that there is no evidence that the swap lines are associated with an increase in trade with China. This is inconsistent with the effect of the swap line being confounded by deepening economic linkages with China in general.

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.

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<sup>13</sup>The distance is measured capital to capital using great circle distance. Alternative measures and thresholds give very similar results.

The RMB swap lines are often 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 Infrastructure 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.

Each of these concerns is dealt with by including controls with a vector of coefficients  $\gamma$  in the linear probability regression. The identifying assumption is the standard one of parallel trends: that the countries which signed the agreement would have had similar RMB usage if they had not done so relative to the countries in our sample that never signed a swap agreement, conditional on the covariates, including the RMB usage of neighboring countries. Abstracting from the immediate months prior to treatment when there is evidence of anticipation, visual inspection of figure 5 suggests no obvious pre-trends (we will confirm this formally below). However, such tests have weak power (see Roth, Forthcoming) and we will revisit identification issues with our specification and consider some alternative strategies in section 4.3.

The third to fifth columns of table 2 consider, incrementally, the 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 14% and 15%. 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. In appendix table A4 we also present results when we split payments into those sent, those received and payments for trade purposes. The swap line has an identical impact on sent and received payments, and payments related to trade.

### 3.3 The intensive margin of RMB usage

Focusing on  $1(\text{Rpayment}_{i,t} > 0)$  as the outcome variable provides estimates for the extensive margin of RMB use, which reflects the presence of zeros in the data. However, if countries were moving from zero to a very small quantity of RMB payments, this would

not be economically meaningful. To address this concern, table 3 considers two specifications designed to estimate the impact of the swap line on the intensive margin of RMB use.

In columns (1)-(2) we replace the left-hand side variable of our baseline staggered difference-in-differences specification with  $Rshare_{i,t}$ . This includes both the extensive margin from jump-starting the currency, as well as the intensive margin of usage. The estimate suggest that signing a swap line agreement raises the share of the RMB in international payment by approximately 1.3 percentage points. This corresponds to about half of the rise in the aggregate RMB share of global payments seen over the course of 2010-2018 (figure 3): an economically significant effect.

Columns (3)-(4) consider an alternative specification that uses a pseudo poisson maximum likelihood (PPML) estimator to deal with the presence of zeros (Santos Silva and Tenreyro, 2006). The quantity of RMB payments now depends multiplicatively on the treatment indicator and the controls, which we estimate using two-way fixed effects.<sup>14</sup> The results suggest that signing a swap line roughly increases RMB usage by 0.9-1.5 log points, or by 64-91%, again an economically significant effect.<sup>15</sup>

### 3.4 Looking for the channel: borrowing costs

Take a bank outside of China that needs to obtain RMB in order to supply trade credit to its customers. Absent a swap line, the bank has two choices. It could borrow the RMB directly, for instance via the offshore RMB money market in Hong Kong. To our knowledge, there is no comprehensive data on country-specific interest rates for RMB-denominated trade credit or wholesale credit. Alternatively, the bank could borrow local currency and then swap it into RMB in the FX swap market. The cost of doing so depends

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<sup>14</sup>The outcome variable can be interpreted as  $\log(Rpayment_{i,t})$  so we augment the control set to include the country's GDP in USD in the quarter, at both market and PPP exchange rates. We also include the country's population, its bilateral exchange with the USD. We modify the trade controls to include the nominal value of imports and exports both in total and to and from China.

<sup>15</sup>This specification comes with some caveats. First, unlike in the trade literature where country pair data is used, our specification is aggregated at the country level. Therefore, there is still an incidental parameters problem when including country-level fixed effects which could bias the effects. Second, the specification is subject to separation, so that conditional on covariates it is possible to perfectly predict certain outcomes, as discussed in Santos Silva and Tenreyro (2010). We use the algorithm provided by Correia, Guimarães and Zylkin (2019) which drops separated observations, this comes at the cost of information on a country's decision not to use the RMB. Third, while the issues surrounding a staggered difference-in-differences design in a linear model have become well established and the literature has come up with solutions, to our knowledge the same is not true for non-linear models like a poisson regression.

on the price of swapping local currency into RMB. This is observable and heterogeneous across countries. Insofar as the two options are close substitutes, the synthetic borrowing rates give a proxy for the direct borrowing rate.

We calculate the synthetic borrowing costs in four ways for each country, using daily data from Refinitiv. All four start from the local currency borrowing cost measured by the interbank offered rate (or equivalent) at a one-year maturity since the start of 2007. The first uses the price of local currency to offshore RMB (CNH) FX swap contracts. The second uses instead swaps to the onshore currency, CNY. The trade settlement scheme that China operates effectively removes any constraints to converting between CNY and CNH for cash flows linked to international trade or trade credit (HKMA, 2009). The Chinese banking system will exchange them one to one, so the two swaps would be equivalent for a bank providing trade credit. The same is not true for speculators which drives a possible wedge between the price of CNH and CNY derivatives.<sup>16</sup> Finally, and because there are no derivatives contracts between some local currencies and either CNH or CNY, we also consider a triangular trade where the bank borrows in local currency first, swaps the local currency into USD and then swaps the USD into CNH or CNY. This gives us two more synthetic borrowing costs. In all four cases, we account for the transaction cost by using the appropriate bid/ask prices.

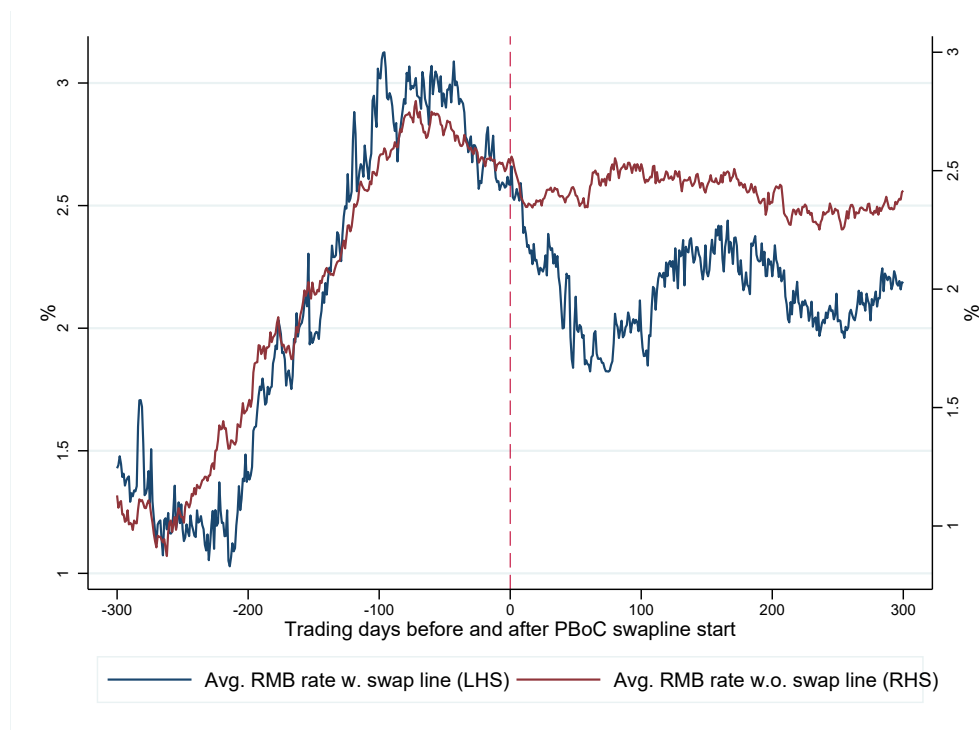
We then assume banks will choose the cheapest of the four options, so our proxy at the country level is the minimum of the four synthetic borrowing costs. If no price information is available for one of the four routes, we assume that the contract is not quoted and the cost of borrowing is infinite. Our final sample is balanced, covers 24 currencies, all of which are issued by central banks that enter a swap agreement at some point during the sample. Appendix A has full details of the dataset construction and the included currencies.

Figure 6 shows the mean path of RMB borrowing costs for countries whose central bank signs an agreement at date 0 (the blue line). The red line shows the mean RMB borrowing costs for all other countries who had not signed a swap line. RMB borrowing costs tend to rise prior to agreements being signed since the PBoC was hiking interest rates in the 2009-2012 period. This creates a parallel trend across all countries. In contrast a gap opens up between countries that sign the agreement at date 0 and other countries

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<sup>16</sup>Also, due to capital controls, CNY contracts that trade offshore are sometimes non-deliverable and settled in USD. A bank that uses a non-deliverable CNY derivative would have to purchase RMB in the spot market as well. However, since wholesale transaction costs in the spot market are low, for trade credit again this should be a minor issue.

Figure 6: Cost of RMB borrowing before and after a swap line is signed



once the swap line is in place: borrowing costs fall on average for countries that sign an agreement.

Table 4 confirms these visual insights formally using the same staggered difference-in-differences methodology that we have used so far.<sup>17</sup> For the full panel of currencies, column (1) shows that signing a swap agreement is associated with an 80bp fall in average RMB borrowing rates. Column (2) uses the spread between local borrowing costs and the relevant RMB interest rate, depending on whether the route was via the CNY or CNH, as the dependent variable.<sup>18</sup> This way, it controls for all time variation in the underlying level of RMB borrowing costs. The result is unaffected. Column (3) uses a 3-month, as opposed to 1-year, tenor and the results are almost unchanged. Finally, column (4) looks only at the sample of emerging market currencies in line with the sample selection criteria in the main analysis. The effect rises to 130bp, suggesting that these countries experience more volatile funding conditions, so that the backstop from the swap line cutting the right tail of borrowing costs is more effective.

<sup>17</sup>We use the last treated group as a control, as there are no never-treated currencies in the sample.

<sup>18</sup>We use SHIBOR rates to capture CNY borrowing costs and HIBOR rates to capture CNH borrowing costs.

Two additional remarks are in order regarding these results. First, we are measuring local banks' wholesale cost of finance in RMB, but the more relevant mechanism (as our model will illustrate) runs through the cost of trade credit for firms. Hence, we are relying on significant passthrough of the effect of the swap lines from the former to the latter. The literature supports this assumption (Bahaj and Reis, 2022*b*), and the operations of the swap lines are consistent with it as well, since the PBoC provides RMB to the local central bank, from there to the local banking system, and finally to firms. Second, the swap line removes the right tail of interest-rate risk, but the regressions show the effect on average borrowing costs. Perhaps these fell because spikes in interest rates were curtailed, or perhaps because the average borrowing costs in some countries were already close to the swap line limit. Since there is no consistent information on the swap line interest rates per country, it is impossible to distinguish between these different cases. However, as will be clear in section 5, either would promote the use of the RMB.

## 4 Digging deeper

While the evidence so far suggests that signing swap agreements is associated with an increase in RMB usage, interpreting the estimates as causal requires that the parallel trends assumption is satisfied. Perhaps, even conditional on fixed effects and covariates, there are still factors that jointly determine the introduction of a swap line and RMB use. Here we consider alternative specifications designed to address this concern, including identification strategies based on spillovers from neighbors and state visits as instruments.

### 4.1 Payments to and trade with China

Several of our covariates and fixed effects tried to deal with the confounding factor that deeper links between the country and China could be driving both RMB usage and signing a swap line. A way to deal with this directly is to estimate the impact of the swap line on economic ties with China through the share of China in the country's (goods) trade. If the effect is null, then this would reject the hypothesis that the swap agreements are only entered into in the anticipation of deepening economic ties with China.

Table 5 replaces the left-hand side variable in equation (1) with the share of China in imports and exports. We also modify the control set to exclude the variables that capture the country's trade with China, included in the baseline specification, and define

Neighbor Trade $_{i,t}$  to be the average of neighboring trade flows with China (either imports or exports depending on the specification). The estimates show that signing a swap line is not associated with an increase in trade with China, whether imports or exports.

A related concern is that the swap line is a by-product of financial integration with China, so it coincides with increases (or expected increases in) RMB payments to or from China for purposes beyond trade. Moreover, as figure 1 makes clear, merely activating the line generates cross-border payments in RMB between the country's central bank and the PBoC. Table 6 repeats the baseline regressions excluding the use of the RMB in payments to and from China (and recall that Hong Kong and Macau are integrated into China in our sample). The effects are approximately unchanged. Our estimates show a jump-start of RMB usage with other countries, beyond China.

## 4.2 Dynamic treatment effects

A separate issue is pre-trends, namely the slight rise in RMB use in the few months just before the agreement being signed. Perhaps this was a sign of a shock that triggered both the swap line signature and a rise in RMB. This seems unlikely, given lags involved in negotiating an agreement, but can be more formally investigated by controlling for the time before the swap line is used. More interesting, the baseline estimates in table 2 treat the effect of signing an agreement as static, having a constant effect post-treatment and nil effect pre-treatment. Yet, figure 2 suggests the impact builds over time with some evidence of anticipation.

Table 7 shows what happens when we allow the treatment effect to vary with the distance from treatment. Columns (1)-(2) separate the effects of a swap line between the first 12 months, and the remaining months after the swap line was signed. Consistent with a jump-start, almost all of the effect happens within 12 months of signing the swap line, as firms make their currency decisions staggered over time.

After 12 months, the effect is slightly larger, so there is no sign of reversion. An implication of these persistent effects is a rejection of 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. If the swap lines were just for political grandstanding we would have expected the estimated effects to have vanished once the RMB became part of the SDR in 2015.

Column (3) in table 2 accounts for pre-treatment effects by allowing the estimation treatment effects in the 12 months prior to treatment (we split the coefficients into two six

month windows). In this specification, therefore, the control period is the period ending a year before treatment. The post agreement effects are robust to this change but now we see that consistent, with figure 5, there is a smaller effect that occurs in the 6 months prior to the swap line being introduced that suggests some anticipation. The coefficient on the period 12-7 months prior to the agreement being is small and not distinguishable from zero, which is what would be expected under parallel trends.

### 4.3 Neighbors and Spillovers

Distance is a key determinant of the size of international trade flows. When a country's neighbor signs a swap line with the PBoC, the country is more likely to import more inputs invoiced in RMB from this neighbor. In turn, this would increase the likelihood that the country jump-starts its own use of the RMB. This provides an alternative way to deal with endogeneity. A neighboring country signing a swap line is arguably orthogonal to the country's economic or political changes that may have simultaneously drove it to sign deals with the PBOC and use the RMB more, especially after controlling for all the region covariates that we already include.

Table 8 shows regressions where the outcome variable is now Neighbor Use $_{i,t}$  measuring the share of RMB usage among the neighbors of the country that signed a swap line. The first column shows the baseline specification with fixed effects. The second column excludes from the calculation of Neighbor Use $_{i,t}$  the neighboring countries that signed a swap line themselves at any point in the sample, to isolate the effect of the single country signing an agreement. The effect remains strikingly large, between 10% and 14%.

If the swap line effect spills over across borders, it will violate the SUTVA assumption, which could bias our estimates. To investigate this, we set up a spillover model (Berg, Reisinger and Streit, 2021) by defining the variable:

$$\text{Neighbor Swap}_{i,t} = \frac{1}{|\mathcal{N}_i|} \sum_{j \in \mathcal{N}_i} \text{SwapLine}_{j,t}, \quad (3)$$

which is the proportion of neighbors that have signed a swap agreement. We then include as covariates Neighbor Swap $_{i,t}$  interacted with SwapLine $_{i,t}$  and  $1 - \text{SwapLine}_{i,t}$ . This accounts for spillovers varying depending on whether the country has an agreement in place, so they take the place of Neighbor Use $_{i,t}$  as a covariate.

Columns (3) and (4) in table 8 show that the baseline effect on the probability of RMB



usage of signing a swap line agreement is unaffected by accounting for spillovers: still 14-15%, although with larger standard errors. However, this now measures the effect assuming no neighboring country has signed a swap line agreement. Accounting for spillovers, the effect of signing a swap line on the probability of RMB usage rises by an additional 30-31% if all neighbors had already signed an agreement, suggesting substantial amplification if multiple countries sign an agreement simultaneously. Similarly, even if a country does not sign an agreement, the effect of all of its neighbors signing an agreement is an increase in the probability of RMB use of 44-46% corroborating the result in columns (1) and (2).

Columns (5) and (6) present the same results as in table 3 on shares of RMB usage to take into account the intensive margin. Accounting for spillovers weakens the direct effect of signing a swap agreement from 1.2-1.3% to 0.8%. Again, there is substantial amplification if all neighboring countries sign the agreement with the estimated effect rising to 2.5% on the share of the RMB in payments. In contrast, the intensive margin effect from neighboring countries signing an agreement conditional on a country not signing an agreement itself is statistically insignificant from zero.

#### 4.4 An instrumental variable approach

We perform one final, demanding, exercise to assess causality through instrumental variables. 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 leadership. 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.<sup>19</sup>

Table 9 re-estimates the effects of the swap line in equation (1), but uses the cumulative number of state visits by the Chinese premier to the country over the course of the sample as an instrument for the swap line.<sup>20</sup> We use a two-way fixed effects estimator, as the Sun and Abraham (2021) estimator does not allow for instrumental variables. The first-stage F-statistics suggest a strong instrument, consistent with swap line agreements typically

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<sup>19</sup>To be clear, it is not the fact that there was a state visit that is being used as an instrument; that would surely not satisfy the exclusion restriction. Rather, it is the *timing* of when that visit happens, comparing countries where this happened earlier to those in which it came later.

<sup>20</sup>These are sourced from the Chinese foreign ministry, see Data Appendix A.

being signed during a state visit. The point estimates from the second stage of a 19% increase in the probability of using the RMB as a result of the swap lines is similar, and a little higher, than the one in the baseline specification.

## 5 A model of currency choices

These empirical findings require a new model. As reviewed in the introduction, there is no theory in the literature that explains why some currencies becomes international (as opposed to why one becomes dominant), why borrowing costs across currencies affect the currency of invoicing (as opposed to features of demand), what is the complementarity between the currency of firm pricing and its liabilities (as opposed to assets), and how central bank policy on lender of last resort directed to trade financing can matter by affecting the borrowing costs through this complementarity. The model in this section does so by capturing in a simple setup the choice of firms over which currency to borrow their working capital in, and the complementary choice of which currency to invoice sales in. We stay as close as possible to the literature on choices of currency invoicing (Engel, 2006, Gopinath, Itskhoki and Rigobon, 2010) and simplify as much as we can the mechanisms it has emphasized, so that we focus solely on their interaction with the choice of borrowing currency.

### 5.1 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. In addition the firm sells to the market of the issuer of the current dominant currency, which we will distinguish by using the subscript  $d$ , and to the market of 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. The markets in the interval  $i \in [0, 1]$  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 7 displays these choices over time.

In period 0, each firm 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 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.

The firm also chooses the currency that will be used to price its goods in the future, just as is standard in the literature. 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  $r$ .<sup>21</sup>

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. 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.<sup>22</sup>

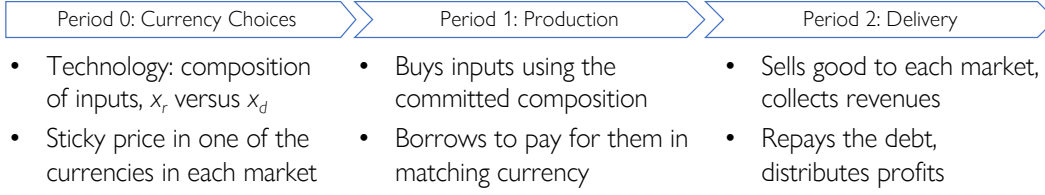
The key risk is on the cost of borrowing, driven by the choice of working capital made in period 0. (There are complementary risks on revenues, given the choice of invoicing currency, and on the cost of the other inputs.) This borrowing risk depends on both the costs of credit in the foreign currency, as well as on the exchange rate of that currency. The price of inputs, exchange rates and borrowing costs are all exogenous.

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<sup>21</sup>In the model, firms choose the currency of their borrowing and their invoicing, but in the data 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.

<sup>22</sup>Christiano and Eichenbaum (1995) is a classic reference.

Figure 7: Each firm's choices and actions over time



## 5.2 Currency of working capital and credit

More concretely, in period 0, each firm  $j$  faces the following production technology:

$$x^j = \min \left\{ \frac{x_r^j}{\eta^j}, \frac{x_d^j}{1 - \eta^j} \right\}. \quad (4)$$

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 local inputs  $l^j$ :

$$y^j = (x^j)^\alpha (l^j)^{1-\alpha}. \quad (5)$$

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. Appendix I allows for these two choices to be different and shows that, in general, the firm will optimally choose to have them be the same.

## 5.3 Cost of production

In order to pay for its working capital, the firm must borrow in period 1. Borrowing  $b_d$  units leads to a repayment of 1 unit in period 2. Instead, borrowing  $b_r$  units in period 1, requires a payment of  $\varepsilon^j$  in period 2. That is, while the interest rate on a  $d$  loan is  $1/b_d$ , the

interest rate on a  $r$  loan is  $\varepsilon^j/b_r$ . Both are known at the time the loan is taken in period 1, but in period 0, firm  $j$  faces uncertainty on  $\varepsilon^j$ , which is drawn from a distribution  $G^j(\varepsilon^j)$  only 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 arises, for example, because the dominant currency enjoys a convenience premium. More generally, the spread of possible interest rates for borrowing in  $r$  can be seen as reflecting the more liquid, stable and efficient capital markets in the  $d$  currency. In our model, this is what defines  $d$  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, potentially, expensive and/or 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 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.

Aside from the firm-specific uncertainty on borrowing costs, there is also uncertainty on the exchange rate with each market  $s_i$ , and on the cost of non-credit inputs  $w$ . After this risk is realized in period 1, the marginal cost of production for firm  $j$  is:

$$C(\eta^j, \varepsilon^j, s_r, s_d, w) = \left[ \frac{\eta^j s_r \rho_r \left(\frac{\varepsilon^j}{b_r}\right) + (1 - \eta^j) s_d \rho_d \left(\frac{1}{b_d}\right)}{\alpha} \right]^\alpha \left( \frac{w}{1 - \alpha} \right)^{1 - \alpha}. \quad (6)$$

## 5.4 Currency of pricing

For the choice of invoicing currency, we follow the standard setup in the literature. In period 0, each firm  $j$  chooses the currency of its sticky price in market  $i$ , among four possibilities:

$$\mathcal{P}_i^j \in \{PCP, LCP, DCP, RCP\}. \quad (7)$$

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. 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  $p_i^j s_r$ .

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  $\theta$ . Its sales depend on the currency in which it sets its price. If the firm follows LCP, then demand is given by:  $y_i^j = (p_i^j / q_i)^{-\theta}$  where  $q_i$  is a stochastic market-specific demand shifter that realizes in period 1. 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:  $y_i^j = (p_i^j / (q_i s_i))^{-\theta}$ . 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:  $y_i^j = (p_i^j s_d / (q_i s_i))^{-\theta}$ . Symmetrically, with RCP:  $y_i^j = (p_i^j s_r / (q_i s_i))^{-\theta}$ .

## 5.5 The goal of each firm

We gather together the shocks to exchange rates,  $s_i$ , and the demand shifters,  $q_i$ , into vectors  $S$  and  $Q$  respectively. These contain the analogues in the  $r$  and  $d$  markets. Accounting for the price of domestic inputs,  $w$ , the stochastic variables that realize in period 1 have joint density  $H(S, Q, w)$ .

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

$$\pi^{LCP}(p_i^j, \eta^j, \varepsilon^j, S, Q, w) = (p_i^j s_i)(p_i^j / q_i)^{-\theta} - C(\eta^j, \varepsilon^j, S, w)(p_i^j / q_i)^{-\theta}. \quad (8)$$

Similar expressions hold for the other three pricing cases, as reported in the appendix.

Combining this profit function with the marginal cost function, and the demand function, the firm's problem is then:

$$\max_{\eta^j} \left( \int_0^1 \max_{p_i^j} \max_{p_i^j} \left( \int \int \pi^P(p_i^j, \eta^j, \varepsilon^j, S, w) dH(S, Q, w) dG^j(\varepsilon^j) \right) di + \dots \right) \quad (9)$$

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, our focus in this paper. The expression omits the equivalent expressions for the  $d$  and  $r$  markets that have positive mass and issue the dominant and rising currencies (the full expression is in the appendix).

## 6 Model predictions

With these ingredients, we now solve the problem in equation (9) and discuss the impact of central bank policies on equilibrium, contrasting these with the empirical results found above.

### 6.1 Forces in the model

With full information, a 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 deliver the optimal constant markup over marginal costs. As for the choice of credit, firms with  $\varepsilon^j > (\rho_d / \rho_r)(b_r / b_d)(s_d / s_r)$  would choose the  $d$  technology since its cost is lower, accounting for the cost of inputs, the cost of credit, and the appreciation of the exchange rate.

With uncertainty though, firms must form expectations of what will be the costs of choosing a different currency. It is important to understand that firms are not averse to uncertainty per se. They maximize expected profits, and so are risk neutral, as in the standard microeconomic theory of the firm. However, ex post deviations from a constant markup over marginal cost lead to lower profits, as do ex post changes in costs of credit and inputs. Therefore, the firm will be averse to the co-movement between the components of total costs, and between marginal costs and demand. This is the *key force* in the model. The focus of our interest are borrowing costs: shocks to either exchange rates or interest rates cause changes in borrowing costs, and affect profits differently depending on the firm's choice of currency for credit and pricing.

To go further and expose the mechanisms driven by this force, we start by making the simplifying assumption that the distribution  $H(S, Q, w)$  is log normal with mean  $\mu$  and  $\Sigma$ .<sup>23</sup> We use subscripts to indicate their elements: mean and variances of the currency of country  $i$  are  $\mu_i$  and  $\sigma_i^2$ , covariance with currency of  $k$  is  $\sigma_{ik}$ , and subscripts  $w$  and  $q$  refer to domestic input costs and demand shifters. Appendix E proves the following result:

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<sup>23</sup>We obtain equivalent results using a second-order approximation with a general distribution (see Appendix K). However, log-normality provides simple analytical solutions.

**Proposition 1.** *The solution to the firm's problem in equation (9) has the following properties:*

- (a) *The firm will choose either to use entirely  $r$ - or  $d$ -credit and inputs,  $\eta^j \in \{0, 1\}$ .*
- (b) *Consider a particular market  $i$  where the firm chooses RCP. If  $\varepsilon^j = 1$  and the  $d$  and  $r$  currencies are otherwise identical in terms of mean, variance and costs, the firm's profit in market  $i$  will increase following a switch from  $d$ -credit to  $r$ -credit if:*

$$\theta \left( \sigma_r^2 - \sigma_{rd} \right) > (1 - \alpha)(\sigma_{rw} - \sigma_{dw}) + \theta (\sigma_{ri} - \sigma_{di}) + \theta (\sigma_{rq_i} - \sigma_{dq_i}). \quad (10)$$

- (c) *If the firm chooses  $r$ -credit, and the  $d$  and  $r$  currencies are otherwise identical in terms of mean and variance, then RCP is preferred to LCP in market  $i$  if the variance of the local exchange rate is sufficiently high:*

$$\sigma_i^2 - 2\alpha\sigma_{ir} - 2(1 - \alpha)\sigma_{iw} \geq \Phi \equiv \sigma_r^2 - 2\alpha\sigma_r^2 - 2(1 - \alpha)\sigma_{rw}. \quad (11)$$

The first result follows from the general result that profit functions are quasi-convex in input prices. Naturally, the firm wants to pick the currency to pay for its inputs and borrow in that has the lowest expected cost. In addition, the firm also wants to choose its inputs to prevent their cost covarying positively with demand or the cost of other factors of production and covarying negatively with prices. There is no desire to diversify because the marginal cost of imported inputs is linear in the two currencies, so one of them will always (weakly) dominate the other when it comes to hedging other risks. Therefore, a bang-bang corner solution is optimal.

The second result shows how the choice of credit allows the firm to hedge different risks. The firm's profits are maximized by maintaining a constant mark up over marginal costs. If the firm uses RCP in a particular market, switching to  $r$ -credit brings the benefit of perfectly aligning a component of marginal cost to the currency of pricing which stabilizes markups. This reveals the complementarity between the pricing choice and the credit choice, which provides an incentive for the firm to use  $r$ -credit the more it prices in  $r$ -currency.

The inequality in proposition 1(b) reveals these hedging factors. On the left-hand side,  $\sigma_r^2 - \sigma_{rd}$  is weakly positive, and precisely reflects that switching from  $d$  to  $r$ -credit aligns prices to the imported portion of marginal costs. On the right-hand side, the first term shows that if  $\sigma_{rw}$  is low relative to  $\sigma_{dw}$ , then  $r$ -credit is also attractive as it is a better hedge for domestic input costs. The second and third terms relate to hedging shifts in demand,



as the firm tries to avoid having high marginal costs at times when it needs to meet high demand. Since this could happen either because  $s_i$  appreciates or because  $q_i$  is large, then  $r$ -credit is less attractive than  $d$ -credit if  $\sigma_{ri} > \sigma_{di}$  or  $\sigma_{rq_i} > \sigma_{dq_i}$ .

Finally, proposition 1(c) considers the choice of pricing currency. This is perhaps less interesting since, unlike the previous two, it follows from well-known results in the literature, but it is worth reviewing for readers less familiar with it. Taking the composition of inputs as given, its desire to keep a constant markup leads the firm to choose the pricing currency to minimize deviations from marginal cost. To see this, start with the case where  $\alpha = 1$  so that the marginal costs of the firm moves entirely with  $s_r$ . Then, the condition is  $\sigma_i^2 \geq -\sigma_r^2 + 2\sigma_{ir}$ , which by the properties of covariance is always true. Thus, the firm would choose RCP over LCP in every market. A higher  $\sigma_i^2$  relative to  $\sigma_r^2$  makes the losses from LCP higher as prices are then more volatile, while a higher covariance  $\sigma_{ir}$  makes LCP resemble RCP more. When  $\alpha < 1$ , 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. An equivalent result applies to the choice of the dominant currency, where  $d$  replaces the  $r$  in the subscripts of the condition.<sup>24</sup>

## 6.2 A brief aside on shocks

Our main focus in this paper is on how access to trade credit alters firm's pricing decisions. Therefore, and to keep expressions simpler from here onwards, we abstract from these hedging channels by making the following assumption:

**Assumption 1.** *The elements of  $\mu$  and  $\sigma$  that relate to the currencies  $d$  and  $r$  are symmetric such that  $\mu_d = \mu_r$ ,  $\sigma_r^2 = \sigma_d^2$ ,  $\sigma_{rw} = \sigma_{dw}$ , and  $\sigma_{ri} = \sigma_{di}$  and  $\sigma_{rq_i} = \sigma_{dq_i}$  for all  $i \in [0, 1]$ . The covariances between  $r$ ,  $d$  and  $q_r$  and  $q_d$  are also symmetric and are restricted such that profits in the  $r$  market are higher under  $r$ -credit if borrowing costs are the same across currencies (symmetric for the  $d$  market).*

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<sup>24</sup>Note that by assuming constant elasticity demand curves, we have ruled out demand complementarities in pricing setting. That is, if prices were fully flexible in period 2, the price that firm  $j$  would set would be independent of the prices set by other firms (or of the demand shifters captured by  $q_i$ ). This is why neither  $\sigma_{rq_i}$  and  $\sigma_{dq_i}$  appear in proposition 1(c). The literature has argued demand complementarities provide a force for the emergence and dominance of an international currency, as firms have an incentive to price in the same currency as their competitors. 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 abstracting from the demand complementarity channel. We discuss how allowing for this complementarity affects our main results in Section 6.7.

This assumption ensures that neither the  $r$  nor the  $d$  currency has an innate advantage over the other, beyond the cost (and uncertainty) of borrowing to buy inputs denominated in each currency. If one of the two currencies is expected to depreciate relative to the other, or if it is significantly more stable, this will favor it in the choices of each firm. These effects are largely isomorphic to just altering the relative interest rates ( $b_d$  and  $b_r$ ) so carrying the extra terms around offers little extra 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, with the USD dominance coming from its deeper financial markets in the model. The last part of assumption 1 deals with demand shocks in the  $d$  and  $r$  markets and simply ensures that the alternative currency is not a sufficiently good hedge that it overcomes the complementarity of matching currencies.

### 6.3 The threshold for borrowing in the rising currency

With these forces at play, the choice of  $\eta^j$  is driven by a threshold rule (appendix F):

**Proposition 2.** *The firm will choose  $r$ -credit ( $\eta^j = 1$ ) if*

$$\left( \int (\varepsilon^j)^\alpha dG^j(\varepsilon^j) \right)^{1/\alpha} \leq \left( \frac{b_r}{b_d} \right) \left( \frac{\rho_d}{\rho_r} \right) \Psi(\mu, \Sigma, \mathcal{P}^j). \quad (12)$$

*Otherwise, it will choose  $d$ -credit. Under assumption 1,  $\Psi(\mu, \Sigma, \mathcal{P}^j)$  is equal to one if the  $r$  and  $d$  markets are equal in size. Starting from this point,  $\Psi(\mu, \Sigma, \mathcal{P}^j)$  is increasing in the size of the  $r$ -market.*

To understand this proposition, first recall that the optimal solution for  $\eta^j$  is bang-bang. Now, consider the case where  $\Psi = 1$ . In these circumstances, the threshold simply states that if the expected value of a concave function of the excess credit costs in  $r$  currency is below the relative interest rates and input costs in the  $r$  and  $d$  currencies, then  $r$  credit is chosen. The interpretation of the threshold becomes whether the cost of  $r$ -credit is low enough relative to  $d$ -credit.

In the case where  $\Psi \neq 1$ , this term captures the way that the distribution of exchange rate volatilities (captured by  $\Sigma$  and  $\mu$ ) interacts with the endogenous choice of invoice pricing (captured by  $\mathcal{P}^j$ ). This includes the complementarities between the currency of

pricing and credit, and any advantages a particular choice of credit has as an hedge. The exact functional form of  $\Psi$  is convoluted and is presented in the appendix. If  $r$  and  $d$  are symmetric in every way, including market size, and only differ in the cost of borrowing and inputs, then all these interactions cancel between the two currencies and  $\Psi = 1$ . However, if the  $r$ -market becomes larger (or the firm prices in the  $r$  currency for another exogenous reason) then the complementarities highlighted above kicks in and raises  $\Psi$ , thus making  $r$ -credit more attractive.

## 6.4 Jump-starting the currency through central bank policies

Proposition 2 shows that the distribution of credit costs in the  $r$  currency,  $G^j(\varepsilon^j)$ , plays a central role. If the expected cost and volatility of  $r$ -credit is low, the firm is more likely to borrow and hence price in  $r$  currency. Currencies where borrowing costs are low and stable are more likely to be used internationally. Central bank policies which remove interest rate risk and lower any premium attached to borrowing in a currency can encourage its internationalization.

As described, a central bank swap line provides a way to borrow foreign currency at a pre-announced interest rate, essentially placing a ceiling on borrowing costs. Hence, we model the introduction of the swap line as giving firms the option to always borrow  $r$  currency at a rate  $\varepsilon^{\text{swap}}/b_r$ , where  $\varepsilon^{\text{swap}}$  is within the support of  $\varepsilon^j$  for some  $j$ .

Appendix G proves the following result on the impact of introducing a swap line:

**Proposition 3.** *The introduction of a swap line that allows firms to obtain  $r$ -credit from the central bank at a known rate  $\varepsilon^{\text{swap}}/q_r$  has the following effects:*

(a) *It shifts the effective distribution of borrowing costs to*

$$\tilde{G}^j(\varepsilon^j) = \begin{cases} 1 & \text{if } \varepsilon^j \geq \varepsilon^{\text{swap}} \\ G^j(\varepsilon^j)/G^j(\varepsilon^{\text{swap}}) & \text{if } \varepsilon^j < \varepsilon^{\text{swap}} \end{cases} \quad (13)$$

*so that  $\tilde{G}^j(\varepsilon^j)$  is first-order stochastically dominated by  $G^j(\varepsilon^j)$  under the new distribution.*

- (b) *Keeping fixed the  $\mathcal{P}^j$  decision, some firms switch from  $\eta^j = 0$  to  $\eta^j = 1$  if the threshold on  $\Psi(\cdot)$  in proposition 2 is crossed when computed using  $\tilde{G}^j(\varepsilon^j)$ .*
- (c) *For firms that switch to  $\eta^j = 1$ , then RCP is always preferred to DCP as long as the correlation between  $s_d$  and  $s_r$  is smaller than one, and RCP is preferred to LCP if the condition in*

proposition 1(c) involving the threshold  $\Phi$  is met. RCP is preferred to PCP if the covariance of the country's non-credit marginal costs with the  $r$  exchange rate is high enough:

$$\sigma_{rw} \geq \Omega \equiv \sigma_r^2 \left( \frac{0.5 - \alpha}{1 - \alpha} \right). \quad (14)$$

The uncertainty around  $\varepsilon^j$  reflects the credit market in  $r$  currency being less stable relative to the  $d$  currency equivalent, so that the terms offered to firms can have a wide distribution. Episodes of high borrowing costs may be rare. The swap line, by cutting the right tail of the distribution, may end up being used quite infrequently and in small volumes. Nonetheless, by removing these infrequent high rates, the line can ex ante significantly affect the firms' inclination to borrow from in the rising currency.

The same result could be achieved through a direct government subsidy trade credit in the rising currency. This would directly shift the  $G^j(\varepsilon^j)$  distribution 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 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 infrequently.

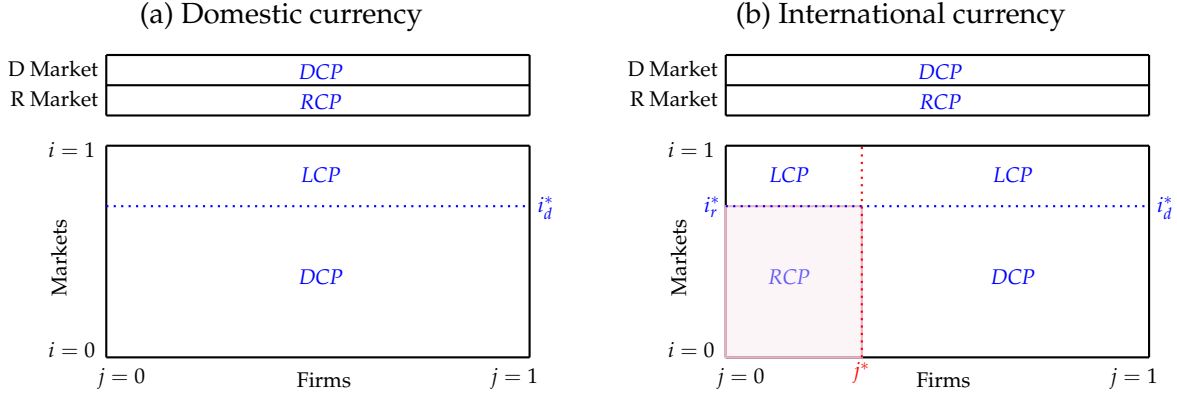
Turning to result (b), the distribution of credit costs affects currency choices through the moment:  $\left( \int (\varepsilon^j)^\alpha d\tilde{G}^j(\varepsilon^j) \right)^{1/\alpha}$ . The effectiveness of the policy is therefore captured by how much this sufficient statistic is altered when computed using the new distribution  $\tilde{G}^j(\varepsilon^j)$ . The firms that cross the new threshold switch from  $d$  credit to  $r$  credit.<sup>25</sup>

Once a firm switches the currency of its credit from  $d$  to  $r$ , then the first part of result (c) notes that it will always want to switch out of the  $d$  currency for its pricing. Since its marginal costs are now partly denominated in the  $r$  currency, but not in  $d$  at all, there is no reason for the firm to use DCP. The second part recalls proposition 1(c) that as long as  $\sigma_r^2$  is small enough, they will not choose LCP. The third part shows that the firms will adopt RCP in some of their markets as long as  $\sigma_{rw}$  is high enough, crossing a third threshold  $\Omega$ . 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  $\sigma_{rw}$

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<sup>25</sup>One result from the empirical analysis is that the swap line does not lead to an increase in trade with China. This is not inconsistent with the model: the swap line effectively subsidizes RMB credit, but not Chinese trade. Recall that we hold the size of the  $r$ -market fixed and we do not specify which countries inputs are purchased from (only the denomination of price).

Figure 8: The impact of the swap line



is large enough, again RCP will achieve higher expected profits.<sup>26</sup>

## 6.5 A graphic display of the model

Figure 8 displays these results graphically using a box. On the horizontal axis are firms, ordered so that the higher is  $j$ , the higher is the volatility of the firm-specific interest rate risk in  $r$  currency,  $\left(\int (\varepsilon^j)^\alpha d\tilde{G}^j(\varepsilon^j)\right)^{1/\alpha}$ . Thus, associated with the threshold  $\Psi$  in proposition 2, 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 are indexed by the inverse of  $\Phi_i$ , as defined in 1(c), so that as we move up, the bilateral exchange rate is increasingly stable (or the local exchange rate is increasingly correlated with  $w$  and  $d/r$ ). This indexing means we can define a threshold market where for  $i \leq i^*$ , pricing in the currency of credit is preferred to pricing in LCP. Finally, the rectangles at the top capture the  $r$  and  $d$  markets, which have positive mass.

Panel a) in the figure shows an  $r$  currency that has not achieved international status. At first,  $j^* = 0$ , and the  $r$  currency is not used at all outside the  $r$ -market. All firms choose  $d$  currency credit, and in the small markets that the firms sell to, none of them chooses RCP. Rather, each firm uses DCP in some markets, and LCP in some other markets (with a threshold market  $i_d^*$  under  $d$ -credit). For the  $r$  market, LCP is the same as RCP. Therefore, the  $r$  currency is only used in trade with the  $r$  country: it is not an international currency.

Panel b) shows the impact of introducing a swap line that lowers expected borrowing

<sup>26</sup>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.

costs enough to cross the threshold in proposition 2. A mass of firms now start borrowing in  $r$  currency and  $j^* > 0$ . In some of their markets, the volatility of the bilateral exchange rate is above the  $\Phi_i$  threshold (proposition 1(c)) so the firms also start invoicing in the  $r$  currency. This is true for a set of markets  $i \in [0, i_r^*]$ . The firms will switch to RCP instead of PCP as the country itself satisfied the  $\Omega$  threshold in proposition 3(c). For markets  $i \in (i_r^*, 1]$ , the bilateral exchange rate is sufficiently stable and the firms choose LCP instead.<sup>27</sup>

In the end, the area of the purple rectangle in figure 8 captures the usage of the  $r$  currency. A further lowering of the swap line rate would increase the length of the rectangle. Both payments sent and received in the  $r$  currency rise, as the two complement each other. This happens not just with respect to the  $r$  country but also to the other countries with which it trades. The currency has jump-started into an international currency status.

## 6.6 Model predictions and evidence

A first fact in the data is that the vast majority of currencies in the world are not international currencies.<sup>28</sup> The model explains this for three complementary reasons: most currencies are far from meeting the thresholds  $\Psi, \Phi, \Omega$ . First, if  $\sigma_r^2$  is large, then the currency will not be used for the pricing of sales, according to proposition 1. Having a stable exchange rate vis-à-vis most other countries is an important pre-condition for policy to have any effect on jump-starting the international use of the currency. Second, for most countries credit is expensive and illiquid in their currencies, so the  $G^j(\cdot)$  distributions are far to the right and the threshold in proposition 2 is far from being met. Third, the countries that issue these currencies are not large enough in international trade neither as markets that firms sell to, nor as sources of intermediate imports. As a result of proposition 3, their  $\Omega$  threshold is small and, hence, harder to clear. If these countries were to try policies to jump-start their currencies, proposition 3 predicts they would fail because none of the thresholds would be overcome. The policies of the People's Bank of China in the 2010s had a chance to succeed because they also came with sound monetary policy,

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<sup>27</sup>Under assumption 1,  $i_r^* = i_d^*$  since the currencies are symmetric. Relaxing the assumption can cause the two threshold markets to differ from one another but this does not matter for the overarching logic of the results.

<sup>28</sup>For example, in October 2018, the final month in our sample of Swift data, 89% of international payments were made in just six currencies: USD, EUR, JPY, GBP, CHF and CNY.

growing capital markets, and large weights in international trade.<sup>29</sup>

A second fact in the data is that most countries did not use the RMB for payments before 2009 and that the signature of a swap line jump-started its use for some. Propositions 1 and 2 explain this. The choice of currency of credit has a bang-bang nature. Because of the complementarity between currency of credit and currency of invoicing, most countries did not use the RMB unless when trading directly with China. The two propositions show that the fall in the cost of Chinese intermediate inputs, the rising size of China as an export market, and the stability of the RMB exchange rate, all contributed to put the RMB close to the threshold in some countries.

The third fact, on the quick jump-start in the use of the RMB, has its counterpart in proposition 3. By shifting the relevant threshold, the swap line was able to shift some firms from using USD to using RMB for their international transactions. It did so by reducing the distribution of borrowing costs in RMB, even if this only happened at the tail and so came, in our sample, with little to no usage of the swap line. At the same time, as figure 8 shows, this jump-start falls well short of the rising currency becoming dominant.

Fourth, in the data, a neighboring country adopting the RMB increased the likelihood that the country used the RMB. In the model, because the country will now likely import more inputs invoiced in RMB from this neighbor, this would raise  $\sigma_{rw}$  as some of the  $w$  costs are now invoiced in  $r$  currency. It is more likely that the threshold in proposition 3c) is met, which in turn leads to a fall in  $\Psi$  in proposition 2 and the jump-start of the RMB. The theory, therefore, matches the fact 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.

## 6.7 Model extensions

The model makes several stark assumptions that we relax in appendices I-L without altering the main conclusions. First, we allow for a separate choice between the currency of borrowing and the currency of pricing of inputs. If the firm faces additional exchange risk between period 1 and 2, under mild conditions, it always prefers these two choices

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<sup>29</sup>This insight allows us to elaborate on what may, at first, seem a critical assumption in our model: that the firm can only buy inputs in  $r$  and  $d$  currencies. We could have allowed the firm source inputs denominated in any of the other currencies that exist in the model. However, the firm would never choose to do so if the threshold in proposition 2 was not satisfied. The assumption that the firm is picking between  $r$  and  $d$  inputs is simply equivalent to assuming the thresholds are not satisfied for other currencies.

to align as we assumed in the main analysis. Second, we drop our assumption of log-normality and allow the production technology to be a generic, homogeneous function of degree one. This latter assumption allows for variable mark-ups and potential demand complementarities in price-setting. To the second-order, the main insights of our main analysis are unchanged, however if the demand complementarities are sufficiently strong this can provide a new force pushing the firm to use the rising currency following the introduction of a swap line.

## 7 Sorting and heterogeneity in the effectiveness of central bank policies

The theory also predicts which countries would be most sensitive to the new policy. This section investigates whether these heterogenous effects are present in the data.

### 7.1 Theoretical predictions on heterogenous effects

Appendix H proves the following:

**Proposition 4.** *Consider a firm that initially uses  $d$ -credit, for whom the distribution of  $\varepsilon^j$  shifts to  $\tilde{G}^j(\varepsilon^j)$  from  $G^j(\varepsilon^j)$ , as defined in proposition 3(a), as a result of a new swap line. The swap line will have a greater impact on the firm's use of the  $r$ -currency, either in terms of picking  $r$ -credit or increasing the share of markets where the firm chooses RCP conditional on choosing  $r$ -credit, if:*

- (a) *the size of the  $r$  market becomes larger, starting from the point where the  $d$  and  $r$  markets are approximately the same size;*
- (b) *domestic costs are closely aligned with the international currencies such that  $\sigma_{rw}$  (and  $\sigma_{dw}$ ) are greater;*
- (c)  *$\alpha$  is higher, so there are more imported inputs using credit.*

The first prediction follows directly from proposition 2(b). The firm prices in currency  $r$  in the  $r$  market and the complementarity between pricing currency and credit currency means that, abstracting from the relative cost of borrowing, profits are greater in the  $r$  market when  $r$ -credit is used. Hence, a larger  $r$ -market raises  $\Psi$ . This means that it is easier for the introduction of a swap line to lead to a switch to  $r$ -credit.



To understand the second prediction in proposition 4, recall that, conditional on using  $r$ -currency, a higher  $\sigma_{rw}$  makes RCP more attractive relative to PCP and LCP. This follows from the definitions of the thresholds  $\Phi_i$  and  $\Omega$  in propositions 1(c) and 3(c). Hence, increasing  $\sigma_{rw}$  means that the  $r$  currency will be used more to price the firm's sales.

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.<sup>30</sup>

The final result in the proposition pertains to a higher  $\alpha$ . In the model this corresponds to a greater share of the inputs requiring working capital. The change in  $\alpha$  has an impact through the left hand side of the threshold in proposition 2a). In particular, the higher  $\alpha$  the greater the change in the expected borrowing costs that arises through the introduction. To see this, start by considering what happens as  $\alpha \rightarrow 0$ . Then working capital plays a minimal role in the firm's cost of production and the reduction in the tail risk of borrowing costs brought about by the swap line has a negligible impact on the firm's choices. As  $\alpha$  increases, the introduction of the swap line generates a greater change in the left-hand side of the threshold in proposition 2a) and, therefore, the firm becomes more likely to cross the threshold and switch to  $r$ -credit.

## 7.2 Empirical Evidence

We now return to the data to test the model's predictions on these country characteristics that make it more likely for a RMB jump-start once a swap line is introduced. We switch back to a two-way fixed estimator of equation (1), and interact  $\text{SwapLine}_{i,t}$  with dummy variables indicating whether the country that signed the agreement was of a particular type.<sup>31</sup> We look at the three dimensions of sorting suggested by the proposition.

<sup>30</sup>Since a part of producer costs are the cost of inputs imported from other countries that are not paid on credit, a neighbor adopting the  $r$  currency would raise  $\alpha$  complementing the effect on  $\sigma_{rw}$  discussed in the previous sub-section.

<sup>31</sup>To our knowledge, there is no staggered difference-in-differences estimator that allows for heterogeneity in treatment effects in any other dimension than treatment time. However, given the two-way fixed effect estimator yielded very similar results to Sun and Abraham (2021) in the baseline case, it seems likely the bias is not material in our context. However, as an alternative, in appendix table A5 we consider estimates using the Sun and Abraham (2021) methodology run on subsamples based on which tertiles the

The first of these is the size of the  $r$  market. In columns (1)-(3) of table 10, we divide the countries in our sample into tertiles by the average share of their goods exports that go to China over the sample period. The point estimate of the effect of a swap line on the probability of RMB use is almost double for countries in the upper tertile of exporters to China compared to the lower tertile. This difference is not statistically significant, however.

Second, the model predicts 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. 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. Columns (4)-(6) of table 10 shows the results for the countries sorted by this covariance. Consistently with the theory, the effects of the swap line are larger in countries with a higher covariance, and the F-statistic shows that this difference is statistically significant.

Third, and finally, a larger dependence on working capital and imported inputs in production leads to needing more trade finance, and so more sensitivity to the swap line. In the model, all imported inputs need working capital so these two concepts were bundled together via the parameter  $\alpha$  in the production function. In the data, we can separate them. We measure reliance on imported inputs as the average share of imports that correspond to intermediates using the BEC trade classification. We measure reliance of working capital by classifying a country's exports to industries by ISIC, and then matching ISIC industries to their reliance on liquidity needs measures using average inventory to sales ratios in US Compustat firms over the period 1980-1999, following Kroszner, Laeven and Klingebiel (2007) and Manova, Wei and Zhang (2015). Using the sample of public US firms is useful because they are likely to have access to finance and working capital so the measure will capture technological differences rather than financial frictions. Given this series and the trade data, we produce an export weighted measure of a country's industrial reliance on working capital, and divide countries into tertiles based on their sample averages.

Columns (7)-(9) and (10)-(12) of table 10 show that the relationship between RMB use and the swap line is, generally increasing in both intermediate input intensity and reliance on working capital. These differences are quantitatively large and statistically significant.

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countries lie in the distribution of trade shares etc. This reduces sample size but the estimates largely confirm the results in table 10.

## 8 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. We put forward a model of the currency choice for credit and showed how it predicts that there will be 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 jump-start the currency. Empirically, we used the RMB swap lines to test for the effects of policy, and for the role of these thresholds. We estimated a 14 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 1.3 percentage points.

There are so few instances of a currency rising to international status in the last century that it is almost impossible to know if these results are specific to China and the RMB. The same, of course, applies to the literature on dominant currencies that almost exclusively relies on US data. However, an analogy from economic history is informative. In 1912, the United States was the world's largest exporter, but US firms and banks used the London financial markets to access trade credit denominated in GBP. The Federal Reserve Act of 1913 allowed US banks to open branches abroad, and the first president of the FRB New York, Benjamin Strong, had an explicit goal of making the USD an international currency. He 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—of which the most striking was to give US banks the ability to discount these acceptances at the Federal Reserve. 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 backstopping the trade acceptances market.<sup>32</sup> By 1925, the USD had become an international currency, and by World War II it had become the dominant currency.

Fast forward almost one century to China in 2009. It was close to being 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 2009, the Chinese government enacted a series of policies to internationalize the RMB, including a scheme for settling trade credits from neighboring countries in RMB, and, of course, signing swap lines with foreign central banks. Banks outside of China could now

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<sup>32</sup>See Eichengreen (2011).

give credit in RMB to local firms knowing that they could get RMB from their local central bank against these trade credits. By 2016, the IMF included the RMB in its SDR basket of international currencies with a weight of 10.9% and by 2019, the RMB accounted for 2.0% of official foreign currency reserves.<sup>33</sup> Taken as a whole, the Chinese policies of the 2010s bear striking resemblances to those pursued by the Fed in the 1910s.

Is it a coincidence that similar policies succeeded, one century apart? The theory and empirics in this paper suggest that the answer is no. Rather, these policies and the Chinese experience with them provides valuable lessons for the theory of why some currencies rise to international status. At the same time, this comparison suggests that for the RMB to rise further in international usage and challenge for the status of a dominant currency requires going well beyond the swap line, or relying on an equilibrium shift in a multiple-equilibrium world. Rather, it will take further policies to remove the many controls to capital in China, as well as some luck in a shock to the USD dominance (like World War I was for sterling). Is this desirable? Whether the swap lines were the best tool to trigger the jump-start, and whether the costs of policies do not outweigh the benefits 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.

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<sup>33</sup>See Prasad (2016), Eichengreen and Lombardi (2017) and IMF dataset on currency composition of official foreign exchange reserves.

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Table 1: Summary statistics: main regression sample

	mean	p50	min	max	sd
<i>RMB payments</i>					
RMB payment sent/received ( $1(\text{Rpayment}_{i,t} > 0)$ )	.258	0	0	1	.438
RMB payment sent/received excluding to/from China	.133	0	0	1	.340
RMB payment sent	.257	0	0	1	.438
RMB payment received	.258	0	0	1	.438
RMB trade credit sent/received (MT400 or MT700)	.050	0	0	1	.217
RMB share in all payments ( $\text{Rshare}_{i,t}$ )	.004	0	0	.925	.033
<i>Economic Linkages with China</i>					
Goods exports to China (% GDP)	.095	.026	0	.964	.158
Goods imports from China (% GDP)	.128	.112	0	.787	.082
Chinese direct investment (% GDP)	.017	0	0	24.64	.262
<i>Neighbor Variables</i>					
Share of neighbors using RMB ( $\text{Neighbor Use}_{i,t}$ )	.271	.2	0	1	.267
Share of neighbors with swap line ( $\text{Neighbor Swap}_{i,t}$ )	.099	0	0	.8	.156
<i>China policies</i>					
Has a PBoC Swap Line ( $\text{SwapLine}_{i,t}$ )	.091	0	0	1	.287
Membership of AIIB	.067	0	0	1	.251
Has RMB Clearing Bank	.018	0	0	1	.134
Has Free Trade Agreement	.009	0	0	1	.093
Cumulative number of state visits	.136	0	0	6	.456
<i>Country Characteristics</i>					
Intermediate input share	.466	.473	.076	.802	.112
Export working capital needs	.150	.151	.080	.206	.021
Observations	12804				

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)
SwapLine <sub><i>i,t</i></sub>	0.2861*** (0.039)	0.1403*** (0.020)	0.1382*** (0.017)	0.1386*** (0.017)	0.1501*** (0.022)
Country f.e.	Yes	No	No	No	No
Country × Seasonal f.e.	No	Yes	Yes	Yes	Yes
Time f.e.	No	Yes	Yes	Yes	Yes
Neighbor Use Control	No	No	Yes	Yes	Yes
China Trade Controls	No	No	No	Yes	Yes
China Policy Controls	No	No	No	No	Yes
Observations	12804	12804	12804	12804	12804

S.E. clustered by country and time in parentheses, \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Notes: Estimates of equation 1 using the Sun and Abraham (2021) methodology; never treated countries are the control group. Sample covers 132 countries over the period October 2010 to October 2018. The outcome variable 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 (SwapLine<sub>*i,t*</sub>). 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 time fixed effects to control for common trends. Column (3): as previous, but includes Neighbor Use<sub>*i,t*</sub> 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 AIB and the presence of an RMB clearing bank and Chinese investment flows into the country.

Table 3: The effect of the swap lines on share of RMB in payments

	Rshare <sub><i>i,t</i></sub>		PPML	
	Time & Seasonal f.e. (1)	All Controls (2)	Time & Seasonal f.e. (3)	All Controls (4)
SwapLine Agreement <sub><i>i,t</i></sub>	0.0123*** (0.002)	0.013*** (0.002)	1.4971*** (0.271)	0.9341*** (0.291)
Country f.e.	No	No	No	No
Country × Seasonal f.e.	Yes	Yes	Yes	Yes
Time f.e.	Yes	Yes	Yes	Yes
Neighbor Use Control	No	Yes	No	Yes
China Trade Controls	No	Yes	No	Yes
China Policy Controls	No	Yes	No	Yes
Observations	12804	12804	6432	4751

S.E. clustered by country and time in parentheses, \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Notes: Columns (1)-(2) Estimates of equation 1 where the LHS is replaced by Rshare<sub>*i,t*</sub>, 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 132 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. Estimation conducted using the Sun and Abraham (2021) methodology with never treated as controls. Column (1): includes only country by calendar-month and time fixed effects, the treatment dummy and no further controls. Column (2): includes additional controls for Neighbors, China trade flows and dummies for membership of the AIIB and the presence of an RMB clearing bank as well as the size of Chinese investment flows into the country. Columns (3)-(4) : Implements a Pseudo-Poisson model for the value of RMB payments (Santos Silva and Tenreiro (2006)). Column (3): estimates the Pseudo-Poisson model with two-way fixed effects and the treatment dummy. Column (4): as previous, but includes as extra controls for China trade, the size of the country's economy and population, the local currency exchange rate and dummies for membership of the AIIB and the presence of an RMB clearing bank and Chinese investment flows into the country. Sample size varies due to the dropping of separated observations.

Table 4: The effect of the swap lines signed on RMB borrowing costs

	Baseline (1)	Spread v Chinese Rate (2)	3 month tenor (3)	Emerging Markets Only (4)
SwapLine <sub><i>i,t</i></sub>	-0.7937** (0.322)	-0.8254** (0.318)	-0.7466** (0.336)	-1.296** (0.594)
Country Fixed Effects	Yes	Yes	Yes	Yes
Trading Day Fixed Effects	Yes	Yes	Yes	Yes
Observations	66727	66727	68137	37296
Number of Countries	24	24	24	14

S.E. clustered by country and time in parentheses, \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

*Notes: Estimates of equation 1 using the Sun and Abraham (2021) methodology; last treated country is the control group. Sample covers 24 currencies in a balanced panel covering trading days from 1st June 2007-8th June 2021. The outcome variable is the country specific estimate of the synthetic RMB borrowing cost as computed in Appendix A. The variable of interest is a dummy variable indicating whether the country's central bank, as of trading day  $t$ , has ever signed a swap line agreement with the PBoC. Column (1): baseline specification with two-way fixed effects and the treatment indicator estimated over the balance panel. Column (2): redefines the the outcome variable to be the spread over the equivalent offshore or onshore Chinese borrowing cost. Column (3): uses a three month tenor rather than a one year tenor. Column (4): restricts the sample only to the emerging markets countries used in the main analysis (see section ), sample reduced to 14 currencies.*

Table 5: The effect of the swap lines on trade with China

	Trade Shares with China			
	Imports		Exports	
	Time & Seasonal f.e. (1)	Incl. Controls (2)	Time & Seasonal f.e. (3)	Incl. Controls (4)
SwapLine <sub><i>i,t</i></sub>	-0.0023 (0.003)	-0.0017 (0.004)	-0.0093 (0.006)	-0.0090 (0.006)
Country f.e.	No	No	Yes	No
Country×Seasonal f.e.	Yes	Yes	No	Yes
Time f.e.	Yes	Yes	No	Yes
Neighbor Trade Control	No	Yes	No	Yes
China Policy Controls	No	Yes	No	Yes
Observations	12804	12804	12804	12804

S.E. clustered by country and time in parentheses, \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Notes: Estimates of equation 1, using Sun and Abraham (2021) where the LHS is replaced by the share of trade a country  $i$  in month  $t$  with China (goods trade only). Sample covers 132 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. First two columns relate to the import share, second two columns relate to the export share. Column (1) and (3): includes country fixed effects that vary by calendar month to control for country specific seasonal factors and month fixed effects. Column (2) and (4): includes fixed effects as well as controls for neighbor trade shares with China, Chinese investment flows into the country, a Chinese FTA dummy, and dummies for membership of the AIIB and the presence of an RMB clearing bank.

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)
SwapLine <sub><i>i,t</i></sub>	0.2382*** (0.045)	0.1173*** (0.034)	0.1066*** (0.029)	0.1097*** (0.029)	0.1072*** (0.027)
Country f.e.	Yes	No	No	No	No
Country × Seasonal f.e.	No	Yes	Yes	Yes	Yes
Time f.e.	No	Yes	Yes	Yes	Yes
Neighbor Use Control	No	No	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

S.E. clustered by country and time in parentheses, \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Notes: Estimates of equation 1 using the Sun and Abraham (2021) methodology; never treated countries are the control group. Sample covers 132 countries over the period October 2010 to October 2018. The outcome variable is an indicator variable for whether the country sends or receives a payment denominated in RMB in a particular month, excluding payments to and from China (including Hong Kong and Macau), 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 (SwapLine<sub>*i,t*</sub>). 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 time fixed effects to control for common trends. Column (3): as previous, but includes Neighbor Use<sub>*i,t*</sub> 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 presence of an RMB clearing bank and Chinese investment flows into the country.

Table 7: Dynamic effects of the swap lines

	Time & Seasonal f.e. (1)	All Controls (2)	Pre- Periods (3)
SwapLine: first 12 months $_{i,t}$	0.1251*** (0.033)	0.1339*** (0.034)	0.1499*** (0.035)
SwapLine: after 12 months $_{i,t}$	0.1433*** (0.049)	0.1500*** (0.047)	0.1631*** (0.045)
SwapLine: 6 months prior $_{i,t}$			0.0918*** (0.028)
SwapLine: 12-7 months prior $_{i,t}$			0.0462 (0.029)
Country f.e.	No	No	No
Country $\times$ Seasonal f.e.	Yes	Yes	Yes
Time f.e.	Yes	Yes	Yes
Neighbor Use Control	No	Yes	Yes
China Trade Controls	No	Yes	Yes
China Policy Controls	No	Yes	Yes
Observations	12804	12804	12804

S.E. clustered by country and time in parentheses, \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Notes: Estimates of equation 1 allowing the effect of  $SwapLine_{i,t}$  to vary with the distance from the agreement being implemented using the Sun and Abraham (2021) methodology. The sample covers 132 countries over the period October 2010 to October 2018. Outcome variable is an indicator 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): specification only includes fixed effects. Column (2) includes all covariates. Column (3): adds two pre-treatment periods.

Table 8: Spillover effects of the swap lines on RMB in payments

Outcome Variable:	Neighbor Use <sub><i>i,t</i></sub>		1(Rpayment <sub><i>i,t</i></sub> > 0)		Rshare <sub><i>i,t</i></sub>	
	All Neighbors (1)	Ex. Neighbors with Swapline (2)	Time & Seasonal f.e. (3)	Incl. Controls (4)	Time & Seasonal f.e. (3)	Incl. Controls (4)
SwapLine <sub><i>i,t</i></sub>	0.1381*** (0.015)	0.0984*** (0.018)	0.1363 (0.123)	0.1513 (0.126)	0.0082** (0.004)	0.0079** (0.004)
SwapLine <sub><i>i,t</i></sub> × Neighbor Swap <sub><i>i,t</i></sub>			0.3124 (0.425)	0.3009 (0.457)	0.0163 (0.010)	0.0174* (0.009)
(1 – SwapLine <sub><i>i,t</i></sub> ) × Neighbor Swap <sub><i>i,t</i></sub>			0.4566*** (0.172)	0.4445** (0.170)	-0.0036 (0.005)	-0.0028 (0.005)
Country f.e.	No	No	No	No	No	No
Country × Seasonal f.e.	Yes	Yes	Yes	Yes	Yes	Yes
Time f.e.	Yes	Yes	Yes	Yes	Yes	Yes
China Trade Controls	No	No	No	Yes	No	Yes
China Policy Controls	No	No	No	Yes	No	Yes
Observations	12804	12804	12804	12804	12804	12804

S.E. clustered by country and time in parentheses, \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Notes: Sample covers 132 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. Columns (1) Estimates of equation 1 where the LHS is replaced by Neighbor Use<sub>*i,t*</sub>. Specification 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 excludes countries that have ever signed a swap agreement with the PBoC from the Neighbor Use<sub>*i,t*</sub> variable. Column (3): Estimates a spillover model including as covariates Neighbor Swap<sub>*i,t*</sub> interacted with SwapLine<sub>*i,t*</sub> and  $1 - \text{SwapLine}_{i,t}$  alongside country by calendar month fixed effects and time fixed effects. Outcome variable is  $1(\text{Rpayment}_{i,t} > 0)$ , 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 (4), as previous and includes as extra controls a Chinese FTA dummy and trade flows with China, dummies for membership of the AIIB and the presense of an RMB clearing bank, and Chinese investment flows into the country. All estimates use the Sun and Abraham (2021) methodology, never treated countries are the control group. Columns (5)-(6): as column (3)-(4) but outcome variable is Rshare<sub>*i,t*</sub>.



Table 9: The effect of the swaplines: state visit IV

	full sample	
	Time & Seasonal f.e. (1)	All controls (2)
SwapLine <sub><i>i,t</i></sub>	0.1878** (0.082)	0.1875 (0.128)
Country f.e.	No	No
Country × Seasonal f.e.	Yes	Yes
Time f.e.	Yes	Yes
Neighbor Use Control	No	Yes
China Trade Controls	No	Yes
China Policy Controls	No	Yes
First stage F-stat	111.3	74.6
Observations	12804	

S.E. clustered by country and time in parentheses

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Notes: Estimates of equation 1 using a two-way fixed effects estimator. 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. The dummy is instrumented with the cumulative number of state visits to the country by the Chinese premier over the course of the sample. The sample covers 132 countries over the period October 2010 to October 2018. The outcome variable 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. First stage F-stat refers to the Kliebergen-Paap statistic. 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 as extra controls Neighbor Use<sub>*i,t*</sub>, a Chinese FTA dummy, trade flows with China, dummies for membership of the AIIB and the presence of an RMB clearing bank, and Chinese investment flows into the country.

Table 10: The effect of the swaplines: heterogeneous responses

	Chinese Trade Share			Price Covariance			Intermediate Imports Share			Export Working Capital Needs		
	low (1)	medium (2)	high (3)	low (4)	medium (5)	high (6)	low (7)	medium (8)	high (9)	low (10)	medium (11)	high (12)
SwapLine <sub>i,t</sub>	0.1458 (0.132)	0.1056 (0.121)	0.2524*** (0.095)	-0.0593 (0.074)	0.0341 (0.233)	0.1821 (0.142)	-0.0620 (0.048)	0.1761 (0.134)	0.2309*** (0.086)	-0.0403 (0.083)	0.2130** (0.082)	0.1672 (0.109)
Country f.e.	No	No	No	No	No	No	No	No	No	No	No	No
Country×Seasonal f.e.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time f.e.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Neighbor Use Control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
China Trade Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
China Policy Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	12804	12804	12804	4268	4268	4268	12707	12707	12707	12707	12707	12707
Number of Countries	132	132	132	46	46	46	131	131	131	131	131	131
F-stat high vs low	0.05	0.05	0.05	2.99*	2.99*	2.99*	10.17*	10.17*	10.17*	10.17*	10.17*	2.77*

S.E. clustered by country and time in parentheses, \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Notes: Estimates of equation 1 with SwapLine<sub>i,t</sub> interacted with an indicator variable for whether country falls in a particular group. Estimation conducted with a two way fixed effects estimator. Columns (1)-(3): Presents the interaction coefficients of SwapLine<sub>i,t</sub> with dummies indicating whether the country is in the lower, middle or upper tertile of sample trade with China (note the three columns correspond to a single regression). Columns (4)-(6) repeats the exercise sorting countries into tertiles based on the correlation between country i's RMB exchange rate and its PPI inflation rate. Correlations are computed in terms of 12 month growth rates over the sample. Limited availability of PPI data means that the sample covers 46 countries (13 treated over the period October 2010 to October 2018. Columns (7)-(9) repeats the exercise for the intermediate import share and columns (10)-(12) for the working capital of exports. See A for exact definitions of these variables. All specifications include the complete control set: neighbor use, China trade and investment flows, and dummies for membership of the AIB, a FTA with China and the presence of an RMB clearing bank.

# Appendix – For Online Publication

## A 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.

**Monthly 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). The monthly trade data are used as controls in our specifications and are the dependent variable in table 5. Exports are measured as the value of goods 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.

**Data on composition of trade.** We use data from BACI on the composition of trade flows. These are used to sort countries into different groups in table 10 and in no other specification. The BACI data is sourced from the UN comtrade database, 2021 vintage. The data is annual, from 2007-2019, and covers goods trade only, at the country-pair-flow-product level. Product codes are defined using the UN Harmonised System (HS) at the six digit level; we use the HS 2007 classification as it is both available from the start of our sample and has the required concordances. To compute a country's intermediate inputs share, we first match HS codes to their Broad Economic Category (BEC) code, fourth revision, using UN concordances. The UN defines BEC codes 111, 121, 21, 22, 31, 322, 43 and 53 as intermediates.<sup>34</sup> Given the import data and matched product codes, it is straightforward to compute the average intermediate share of inputs by country. For exporters' reliance on working capital, we match export HS codes to International Standard Industry Classification codes, revision 2. This provides the industry composition of exports. An index of industrial reliance on working capital is provided in Kroszner, Laeven and Klingebiel (2007), using the median inventory to sales ratio for US Compustat firms over the course of 1980-1999. Our final measure at the country level is the industry composition of exports-weighted version of the this index.

**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).

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

**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 web-

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<sup>34</sup>See <https://unstats.un.org/unsd/tradekb/Knowledgebase/50090/Intermediate-Goods-in-Trade-Statistics> (Last accessed April 4th 2022)

site on 21st October of 2019. We use the location of the capital as the 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 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.

**State visit data.** We hand collected data on the dates of state visits by the Chinese premier (Hu Jintao or Xi Jinping) by reviewing all press releases published by the Chinese ministry of foreign affairs over the course of our sample.

## A.1 Computing synthetic RMB borrowing costs

**Data Sources.** We use Refinitiv Eikon to obtain daily data on CNY and CNH FX swaps by counterparty, alongside the corresponding spot exchange rates. We use Refinitiv Datastream to obtain data on local currency interbank offered rates (or equivalent) and FX forward and spot prices versus USD. We separate these series into the bid price and the ask price to account for the transaction costs involved in synthetic borrowing. For comparability, when we use Eikon for the FX derivative rates, we use Eikon for the spot exchange rate and similarly for Datastream. The difference between the two sources when definitions overlap is minimal. The exact tickers are provided in the supplementary materials.

**Sample Currencies.** We obtain data on synthetic RMB borrowing costs for the following 23 currencies: AED, AUD, BRL, CHF, CLP, EUR, GBP, HKD, HUF, IDR, ISK, JPY, KRW, KZT, MYR, NZD, PKR, RUB, SGD, SRL, THB, TRY, ZAR where we were able to compute a high quality borrowing cost measure from the available data. This sample enables us to form a balanced panel starting 1st of June 2007. Note that CNH derivatives only started becoming available around 2011. Most of our earlier observations are constructing via a triangular trade of swapping into USD and then into CNY.

**Constructing RMB borrowing costs.** To construct synthetic RMB rates directly from CNY or CNH FX swaps, for currency  $k$  and on trading day  $t$ , we first calculate the implicit forward rate from the bid prices:

$$f_{r,t}^{k,bid} = s_{r,t}^{k,bid} + swap_{r,t}^{k,bid},$$

where  $r$  denotes RMB, defined as either CNY or CNH,  $swap_{r,t}^{k,bid}$  is the RMB vs currency  $k$  swap rate in swap points and  $s_{r,t}^{k,bid}$  is the spot exchange rates. All exchange rates are defined in terms of local currency  $k$  per unit of  $r$ .

Define the gross interest rate on a loan denominated in currency  $k$  for the same maturity as the swap as  $1/q_k$ . The synthetic cost of RMB borrowing using currency  $k$  as base is then given by:

$$1/\tilde{q}_r^k = s_{r,t}^{k,ask} / (f_{r,t}^{k,bid} \times q_k).$$

Let  $d$  denote USD. When going via the USD we observe  $f_{d,t}^{k,bid}$  directly including for  $k = r$ . Hence, we can compute

$$1/\hat{q}_r^k = (s_{r,t}^{d,ask} / f_{r,t}^{d,bid}) \times s_{d,t}^{k,ask} / (f_{d,t}^{k,bid} \times q_k),$$

as an alternative measure of RMB borrowing costs based on a triangular trade. For our empirical analysis, we have  $r \in \{CNY, CNH\}$  and we define the RMB interest rate for the country issuing currency  $k$  as

$$1/q_{RMB}^k = \min \left( 1/\hat{q}_{CNY}^k, 1/\hat{q}_{CNH}^k, 1/\tilde{q}_{CNY}^k, 1/\tilde{q}_{CNH}^k \right).$$

## B Additional Empirical Results

**Two way-fixed effects estimators.** Table A2 presents the equivalent of table 2 when we use a two-way fixed effects estimator rather than the Sun and Abraham (2021) methodology. Our results are largely unaffected by this switch suggesting the bias caused by heterogeneous treatment effects is small.

**Including developed economies.** Table A3 presents results when we relax the GDP per capita filter on the countries included in our sample. The baseline results are reduced somewhat by including developed economies (columns (1)-(2)), largely because RMB usage in these economies is insensitive to the swap line (columns (3)-(4)).

**Payment types.** The theory included two dimensions: the usage of the  $r$ -currency for credit and for sales. Table A4 splits payments into three types. First, it considers payments received only, corresponding to the choice of  $\mathcal{P}$  in the model. Second, it considers 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 or MT 700). Specifically, we redefine the left hand side variable to take a value of one if the country sends or receives a RMB denominated MT 400 or MT 700 in a particular month (zero otherwise). Across payments sent and received, the results are quite stable, between 13% and 14%. The results on trade credit are similar.

**Sorted specifications with split sample regressions.** In the main text, table 10 used two-way fixed estimators plus interaction terms to estimate heterogeneous treatment effects. In table A5, we instead dispense with interaction terms and use split sample regressions to compute heterogeneous treatment effects. Specifically, we divide the sample into three subsamples based on the tertiles of the dimension of heterogeneity of interest. We then rerun the Sun and Abraham (2021) methodology on each subsample. The results are similar to those in the main text.

## C Profit functions and optimal prices

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

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

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

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

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

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

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

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

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

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



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:

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

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

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

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

## D 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 (9), each firm  $j$  chooses its currency of credit  $\eta^j$  to maximize the profit function  $\Pi^j(\eta^j)$  that is defined by:

$$\begin{aligned} \Pi^j(\eta^j) &= \int_{\Delta^{LCP}(\eta^j)} \pi_i^{LCP*}(\eta^j) di + \int_{\Delta^{PCP}(\eta^j)} \pi_i^{PCP*}(\eta^j) di + \int_{\Delta^{RCP}(\eta^j)} \pi_i^{RCP*}(\eta^j) di \\ &\quad + \int_{\Delta^{DCP}(\eta^j)} \pi_i^{DCP*} di + \delta_r \pi_r^{RCP*}(\eta^j) + \delta_d \pi_d^{DCP*}(\eta^j) \end{aligned} \quad (\text{A13})$$

The four sets in the integrals correspond to the the partition of the continuum of markets the firm sells to 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  $\pi_r^{RCP*}$  and  $\pi_d^{DCP*}$  correspond to profits in the  $r$  and  $d$  markets respectively. These markets have mass  $\delta_r$  and  $\delta_d$ . 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.

## E Proof of proposition 1

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

$$c(\eta^j) = \eta^j s_r \rho_r (\varepsilon^j / b_r) + (1 - \eta^j) s_d (\rho_d / b_d). \quad (\text{A14})$$

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

$$\pi_i^{LCP*}(c(\eta^j)) = \frac{1}{\theta-1} \left( \frac{\theta}{\theta-1} \right)^{-\theta} \mathbb{E}[s_i]^\theta \mathbb{E} \left[ \left( \frac{c(\eta^j)}{\alpha} \right)^\alpha \left( \frac{w}{1-\alpha} \right)^{1-\alpha} \right]^{1-\theta}. \quad (\text{A15})$$

These two functions are continuous and differentiable. Crucially, given our assumptions, the  $\pi_i^{LCP*}(\cdot)$  function only depends on  $\eta^j$  via the  $c(\cdot)$  function. And since the  $c(\eta^j)$  function is linear  $\frac{\partial^2 c(\eta)}{\partial \eta^2} = 0$ . The chain rule then implies that:

$$\begin{aligned} \frac{\partial^2 \pi_i^{LCP*}(c)}{\partial \eta^2} &= \theta \left( \frac{\theta}{\theta-1} \right)^{-\theta} \mathbb{E}[s_i]^\theta \mathbb{E} \left[ \left( \frac{c(\eta^j)}{\alpha} \right)^\alpha \left( \frac{w}{1-\alpha} \right)^{1-\alpha} \right]^{-\theta-1} \mathbb{E} \left[ \frac{\partial c(\eta^j)}{\partial \eta} c(\eta^j)^{\alpha-1} \left( \frac{w}{1-\alpha} \right)^{1-\alpha} \right]^2 \\ &+ (1-\alpha) \left( \frac{\theta}{\theta-1} \right)^{-\theta} \mathbb{E}[s_i]^\theta \mathbb{E} \left[ \left( \frac{c(\eta^j)}{\alpha} \right)^\alpha \left( \frac{w}{1-\alpha} \right)^{1-\alpha} \right]^{-\theta} \mathbb{E} \left[ \left( \frac{\partial c(\eta^j)}{\partial \eta} \right)^2 c(\eta^j)^{\alpha-2} \left( \frac{w}{1-\alpha} \right)^{1-\alpha} \right]. \end{aligned}$$

Both terms on the right-hand side are positive since  $\alpha < 1$ . Therefore:  $\frac{\partial^2 \pi_i^{LCP*}(c)}{\partial \eta^2} \geq 0$ . It is straightforward to verify the same is true under alternative pricing currencies.

Now consider the firm's total profit function across all markets laid out under equation (A13). Start by focussing on the first two terms of the expression for  $\Pi(\eta)$ :

$$\int_{\Delta^{LCP}(\eta)} \pi_i^{LCP*}(\eta) di + \int_{\Delta^{PCP}(\eta)} \pi_i^{PCP*}(\eta) di. \quad (\text{A16})$$

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

$$\int_{\Delta^{LCP}} \frac{\partial \pi_i^{LCP*}}{\partial \eta} di + \int_{\Delta^{PCP}} \frac{\partial \pi_i^{PCP*}}{\partial \eta} di + \underbrace{\pi_k^{LCP*} - \pi_k^{PCP*}}_{=0}, \quad (\text{A17})$$

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:

$$\underbrace{\int_{\Delta^{LCP}} \frac{\partial^2 \pi_i^{LCP*}}{\partial \eta^2} di + \int_{\Delta^{PCP}} \frac{\partial^2 \pi_i^{PCP*}}{\partial \eta^2} di}_{>0} + \underbrace{\frac{\partial \pi_k^{LCP*}}{\partial \eta} - \frac{\partial \pi_k^{PCP*}}{\partial \eta}}_{>0} \quad (\text{A18})$$

where we assumed that the the size of the set  $\Delta^{LCP*}$  increased at the expense of the set

$\Delta^{PCP^*}$  following an increase in  $\eta$ . 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 reverse 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  $r$  and  $d$  keeps the result, since profits in those markets are convex in  $\eta^j$  and 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)** If  $\eta^j = 1$ , marginal costs are equal to

$$C(1, \varepsilon^j, S, w) = \left( \frac{s_r \rho_r (\varepsilon^j / b_r)}{\alpha} \right)^\alpha \left( \frac{w}{1 - \alpha} \right)^{1 - \alpha}. \quad (\text{A19})$$

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:

$$\pi^{LCP^*}(\eta^j = 1) = \Xi \mathbb{E} \left[ s_i q_i^\theta \right]^\theta \mathbb{E} \left[ (s_r)^\alpha (w)^{1 - \alpha} (q_i)^\theta \right]^{(1 - \theta)}, \quad (\text{A20})$$

$$\pi^{PCP^*}(\eta^j = 1) = \Xi \mathbb{E} \left[ (s_i q_i)^\theta \right]^\theta \mathbb{E} \left[ (s_r)^\alpha (w)^{1 - \alpha} (s_i q_i)^\theta \right]^{1 - \theta}, \quad (\text{A21})$$

$$\pi^{RCP^*}(\eta^j = 1) = \Xi \mathbb{E} \left[ (s_r)^{1 - \theta} (s_i q_i)^\theta \right]^\theta \mathbb{E} \left[ (s_r)^{\alpha - \theta} (w)^{1 - \alpha} (s_i q_i)^\theta \right]^{1 - \theta}, \quad (\text{A22})$$

$$\pi^{DCP^*}(\eta^j = 1) = \Xi \mathbb{E} \left[ (s_d)^{1 - \theta} (s_i q_i)^\theta \right]^\theta \mathbb{E} \left[ (s_r)^\alpha (w)^{1 - \alpha} (s_i q_i / s_d)^\theta \right]^{1 - \theta}, \quad (\text{A23})$$

$$\text{where } \Xi \equiv \frac{1}{\theta - 1} \left( \frac{\theta}{\theta - 1} \right)^{-\theta} \mathbb{E} \left[ \left( \frac{\rho_r \varepsilon^j / b_r}{\alpha} \right)^\alpha \left( \frac{1}{1 - \alpha} \right)^{1 - \alpha} \right]^{1 - \theta}. \quad (\text{A24})$$

If  $\eta^j = 0$ , we would instead have  $\Xi \equiv \frac{1}{\theta-1} \left(\frac{\theta}{\theta-1}\right)^{-\theta} \left[\left(\frac{\rho_d/b_d}{\alpha}\right)^\alpha \left(\frac{1}{1-\alpha}\right)^{1-\alpha}\right]^{1-\theta}$  and would swap  $s_r$  for  $s_d$  in the second expectation that appears in each of the four profit functions above.

Under the assumption that  $\varepsilon^j = 1$  and that  $d$  and  $r$  are otherwise identical in terms of mean, variance and costs such that (i)  $\rho_r = \rho_d$ , (ii)  $b_r = b_d$ , (iii)  $\mu_r = \mu_d$  and (iv)  $\sigma_r = \sigma_d$ , then the condition for a switch to  $r$ -credit from  $d$  credit increasing profits in market  $i$  under RCP is:

$$\pi^{RCP^*}(1) > \pi^{RCP^*}(0) \Leftrightarrow \mathbb{E} \left[ s_r^{\alpha-\theta} w^{1-\alpha} s_i^\theta q_i^\theta \right]^{1-\theta} > \mathbb{E} \left[ s_d^\alpha w^{1-\alpha} s_i^\theta s_r^{-\theta} q_i^\theta \right]^{1-\theta}. \quad (\text{A25})$$

Using the properties of the log-normal distributions, and maintaining restrictions on the equality of parameters, this expression simplifies to:

$$\theta \left( \sigma_r^2 - \sigma_{rd} \right) > (1 - \alpha)(\sigma_{rw} - \sigma_{dw}) + \theta (\sigma_{ri} - \sigma_{di}) + \theta (\sigma_{rq_i} - \sigma_{dq_i}) \quad (\text{A26})$$

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

$$\pi_i^{RCP^*}(1) \geq \pi_i^{LCP^*}(1) \Leftrightarrow \quad (\text{A27})$$

$$\mathbb{E} \left[ s_r^{1-\theta} s_i^\theta q_i^\theta \right]^\theta \mathbb{E} \left[ s_r^{\alpha-\theta} w^{1-\alpha} s_i^\theta q_i^\theta \right]^{1-\theta} \geq \mathbb{E} \left[ s_i q_i^\theta \right]^\theta \mathbb{E} \left[ s_r^\alpha w^{1-\alpha} q_i^\theta \right]^{1-\theta} \quad (\text{A28})$$

Assuming log-normal distributions and that  $d$  and  $r$  have the same mean and variance, this expression simplifies to:

$$\sigma_i^2 \geq \sigma_r^2 + 2 \left[ \alpha(\sigma_{ir} - \sigma_r^2) + (1 - \alpha)(\sigma_{iw} - \sigma_{rw}) \right]. \quad (\text{A29})$$

## F Proof of proposition 2

**Part a)** This proof for now assumes that PCP is not used, so  $\Delta^{PCP}(\eta) = \emptyset$ . This would be justified by the condition in proposition 3c) holding. Moreover, proposition 3c) will show that if  $\eta^j = 1$ , 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:

$$\left[ \left( \frac{\rho_r/b_r}{\alpha} \right)^\alpha \int (\varepsilon^j)^\alpha dG^j(\varepsilon^j) \right]^{1-\theta} A_r \geq \left[ \left( \frac{\rho_d/b_d}{\alpha} \right)^\alpha \right]^{1-\theta} A_d \quad (\text{A30})$$

where the two terms are defined as:

$$\begin{aligned} A_r = & \int_{\Delta^{RCP}(1)} \mathbb{E} \left[ s_r^{1-\theta} s_i^\theta q_i^\theta \right]^\theta \left( \mathbb{E} \left[ s_r^{\alpha-\theta} w^{1-\alpha} s_i^\theta q_i^\theta \right] \right)^{1-\theta} di + \int_{\Delta^{LCP}(1)} \mathbb{E} [s_i q_i^\theta]^\theta \mathbb{E} \left[ s_r^\alpha w^{1-\alpha} q_i^\theta \right]^{1-\theta} di \\ & + \delta_r \mathbb{E} [s_r q_r^\theta]^\theta \mathbb{E} \left[ s_r^\alpha w^{1-\alpha} q_r^\theta \right]^{1-\theta} + \delta_d \mathbb{E} [s_d q_d^\theta]^\theta \mathbb{E} \left[ s_r^\alpha w^{1-\alpha} q_d^\theta \right]^{1-\theta}. \end{aligned} \quad (\text{A31})$$

$$\begin{aligned} A_d = & \int_{\Delta^{DCP}(0)} \mathbb{E} \left[ s_d^{1-\theta} s_i^\theta q_i^\theta \right]^\theta \left( \mathbb{E} \left[ s_d^{\alpha-\theta} w^{1-\alpha} s_i^\theta q_i^\theta \right] \right)^{1-\theta} di + \int_{\Delta^{LCP}(0)} \mathbb{E} [s_i q_i^\theta]^\theta \mathbb{E} \left[ s_d^\alpha w^{1-\alpha} q_i^\theta \right]^{1-\theta} di \\ & + \delta_r \mathbb{E} [s_r q_r^\theta]^\theta \mathbb{E} \left[ s_d^\alpha w^{1-\alpha} q_r^\theta \right]^{1-\theta} + \delta_d \mathbb{E} [s_d q_d^\theta]^\theta \mathbb{E} \left[ s_d^\alpha w^{1-\alpha} q_d^\theta \right]^{1-\theta}. \end{aligned} \quad (\text{A32})$$

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

Relaxing the assumption that  $\Delta^{PCP}(\eta) = \emptyset$  simply adds the expected revenues from the set of PCP markets to the two equations.

**Part b)** First note that under assumption 1, we have  $\Delta^{DCP}(0) = \Delta^{RCP}(1)$  and  $\Delta^{LCP}(0) = \Delta^{LCP}(1)$ . Moreover, under the assumption, all the expectations mirror one another; that is:  $\mathbb{E} [s_r^{\alpha-\theta} w^{1-\alpha} s_i^\theta q_i^\theta] = \mathbb{E} [s_d^{\alpha-\theta} w^{1-\alpha} s_i^\theta q_i^\theta]$  etc. Hence, so long as  $\delta_r = \delta_d$ ,  $\Psi = 1$ .

Starting from this point an increase in  $\delta_r$  raises  $A_r$  by:

$$\mathbb{E} [s_r q_r^\theta]^\theta \mathbb{E} \left[ s_r^\alpha w^{1-\alpha} q_r^\theta \right]^{1-\theta},$$

and  $A_d$  by

$$E \left[ s_r q_r^\theta \right]^\theta \mathbb{E} \left[ s_d^\alpha w^{1-\alpha} q_r^\theta \right]^{1-\theta}.$$

Assumption 1 ensures that  $\mathbb{E} [s_r^\alpha w^{1-\alpha} q_r^\theta]^{1-\theta} > \mathbb{E} [s_d^\alpha w^{1-\alpha} q_r^\theta]^{1-\theta}$ . Hence,  $A_r$  increases by more than  $A_d$ . So long as  $A_r \geq A_d$  this amounts to an increase in  $\Psi$ .

## G Proof of proposition 3

**Part a)** This follows immediately from the description of how the swap line works, and the definition of borrowing costs.

**Part b)** This follows directly from proposition 2.

**Part c)** Using the profits under the different pricing regimes stated in the proof of 2, the firm prefers RCP over DCP in market  $i$  if:

$$\pi_i^{RCP*}(1) \geq \pi_i^{DCP*}(1) \Leftrightarrow \quad (A33)$$

$$\mathbb{E} \left[ s_r^{1-\theta} s_i^\theta q_i^\theta \right]^\theta \mathbb{E} \left[ s_r^{\alpha-\theta} w^{1-\alpha} s_i^\theta q_i^\theta \right]^{1-\theta} \geq \mathbb{E} \left[ s_d^{1-\theta} s_i^\theta q_i^\theta \right]^\theta \mathbb{E} \left[ s_r^\alpha w^{1-\alpha} s_d^{-\theta} s_i^\theta q_i^\theta \right]^{1-\theta}. \quad (A34)$$

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:

$$\left[ \alpha \left( \sigma_r^2 - \sigma_{rd} \right) \right] \geq (1 - \alpha) \left( \sigma_{dw} - \sigma_{rw} \right) - \frac{\sigma_r^2 - \sigma_d^2}{2}. \quad (A35)$$

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 that  $\sigma_{rw} = \sigma_{dw}$ . Therefore the condition boils down to  $\sigma_r^2 - \sigma_{rd} \geq 0$  which is always true unless the two currencies are perfectly correlated.

Next, the firm prefers RCP over PCP if:

$$\pi_i^{RCP*}(1) \geq \pi_i^{PCP*}(1) \Leftrightarrow \quad (A36)$$

$$\mathbb{E} \left[ s_r^{1-\theta} s_i^\theta q_i^\theta \right]^\theta \mathbb{E} \left[ s_r^{\alpha-\theta} w^{1-\alpha} s_i^\theta q_i^\theta \right]^{1-\theta} \geq \mathbb{E} \left[ s_i^\theta q_i^\theta \right]^\theta \mathbb{E} \left[ s_r^\alpha w^{1-\alpha} s_i^\theta q_i^\theta \right]^{1-\theta} \quad (A37)$$

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

$$(2\alpha - 1)\sigma_r^2 + 2(1 - \alpha)\sigma_{rw} \geq 0 \Leftrightarrow \sigma_{rw} \geq \sigma_r^2 \left( \frac{0.5 - \alpha}{1 - \alpha} \right) \equiv \Omega. \quad (A38)$$

This proves the result.

## H Proof of proposition 4

**Part a)** This follows immediately from proposition 2(b).

**Part b)** An increase in  $\sigma_{rw}$  and  $\sigma_{dw}$ , alters the thresholds  $\Phi_i$  per proposition 1(c) and  $\Omega$  per proposition 3(c) such that RCP becomes attractive compared to LCP and DCP.

**Part c)** To establish this result, let us start with a simplified case where  $\varepsilon$  is binary. Specifically,  $\varepsilon \in \{A, B\}$  with  $B > A$ , and  $Pr(\varepsilon = A) = \omega$ . We will assume that  $A < \varepsilon^{swap} < B$ . In which case, the question becomes is the ratio  $\left(\frac{\omega A^\alpha + (1-\omega)B^\alpha}{A^\alpha}\right)^{1/\alpha}$  increasing or decreasing in  $\alpha$ ?

This is true if

$$\frac{d}{d\alpha} \left( \frac{1}{\alpha} \log(\omega A^\alpha + (1-\omega)B^\alpha) \right) > \frac{d}{d\alpha} \left( \frac{1}{\alpha} \log(A^\alpha) \right),$$

or

$$\frac{\omega \log(A)A^\alpha + (1-\omega) \log(B)B^\alpha}{\omega A^\alpha + (1-\omega)B^\alpha} - \frac{1}{\alpha} \log(\omega A^\alpha + (1-\omega)B^\alpha) > \frac{\log(A)A^\alpha}{A^\alpha} - \frac{1}{\alpha} \log(A).$$

This expression can be rearranged to yield

$$\frac{(1-\omega)B^\alpha}{\omega A^\alpha + (1-\omega)B^\alpha} \log(B^\alpha) + \frac{\omega A^\alpha}{\omega A^\alpha + (1-\omega)B^\alpha} \log(A^\alpha) > \log((1-\omega)(B^\alpha) + \omega(A^\alpha)). \quad (\text{A39})$$

Note that while  $\frac{(1-\omega)B^\alpha}{\omega A^\alpha + (1-\omega)B^\alpha} + \frac{\omega A^\alpha}{\omega A^\alpha + (1-\omega)B^\alpha} = 1$ , standard Jensen's inequality result for a concave function does not apply in this context as left-hand side uses different weights compared to the right hand side. Now as  $B \rightarrow A$  both sides of the expression tend to  $\alpha \log(A)$ : when  $B = A$ , the ratio of interest is unity and hence the derivative with respect to  $\alpha$  is nil. Starting from the point  $B = A$ , it is therefore sufficient to prove that the right hand side in equation (A39) is increasing in  $B$  faster than the left hand side. This is true if

$$\begin{aligned} & \frac{(\omega A^\alpha + (1-\omega)B^\alpha)(1-\omega)B^{\alpha-1}(\alpha \log(B^\alpha) + \alpha)}{(\omega A^\alpha + (1-\omega)B^\alpha)^2} \\ & - \frac{\alpha(1-\omega)B^{\alpha-1}(\omega \log(A^\alpha)A^\alpha + (1-\omega)B^\alpha \log(B))}{(\omega A^\alpha + (1-\omega)B^\alpha)^2} > \frac{\alpha(1-\omega)B^{\alpha-1}}{(\omega A^\alpha + (1-\omega)B^\alpha)^2}, \end{aligned}$$

or

$$\log(B^\alpha) > \frac{\omega A^\alpha}{(\omega A^\alpha + (1-\omega)B^\alpha)} \log(A^\alpha) + \frac{(1-\omega)B^\alpha}{(\omega A^\alpha + (1-\omega)B^\alpha)} \log(B^\alpha).$$

Which is always true for  $B > A$ . Hence, we have that inequality in equation (A39) is satisfied for any  $B > A$ .

It is straightforward to extend these steps to a general distribution so long the swap line has a  $\varepsilon^s$  that truncates it.

## I Model extension: 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 rates in period 1 and 2 are 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 variable  $\zeta^j$  is chosen optimally by the firm and we do not ex-ante restrict the firm from choosing an interior solution. The realised cost of  $x^j$ , as function of both  $\zeta^j$  and  $\eta^j$ , is now given by:

$$\eta^j \tilde{s}_r \left( \rho_r \frac{\varepsilon^j}{b_r} \zeta^j \frac{s_r}{\tilde{s}_r} + \frac{1}{b_d} (1 - \zeta^j) \frac{s_d}{\tilde{s}_d} \right) + (1 - \eta^j) \tilde{s}_d \left( \rho_d \frac{\varepsilon^j}{b_r} \zeta^j \frac{s_r}{\tilde{s}_r} + \frac{1}{b_d} (1 - \zeta^j) \frac{s_d}{\tilde{s}_d} \right). \quad (\text{A40})$$

Note if  $\eta^j = \zeta^j$ , the risk from the intermediate exchange rates are perfectly hedged and we are back to the problem in the main text.

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 and  $q_i = 1$  for all markets, (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 following holds:



**Proposition A1.** *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  $(\eta^j, \zeta^j) = (0,0)$  or  $(\eta^j, \zeta^j) = (1,1)$  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  $\sigma_{i\bar{r}} = \sigma_{i\bar{d}}$ . The sufficient condition under RCP or DCP is  $\sigma_{i\bar{r}} = \sigma_{i\bar{d}}$  and  $\sigma_{\bar{r}\bar{d}} \geq 0$ .*

The choices of currency of credit and currency of inputs are both bang-bang:  $\eta^j \in \{0,1\}$  and  $\zeta^j \in \{0,1\}$ .

The convexity of the profit function extends to both currency choices. The relevant question then is whether the firm ever chooses  $(\eta^j, \zeta^j) = (1,0)$  or  $(\eta^j, \zeta^j) = (0,1)$ , 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 following proof of the proposition.

## J Proof of proposition A1

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

$$c(\eta^j, \zeta^j) = \eta^j \bar{s}_r \rho_r \left( \frac{\varepsilon^j}{b_r} \zeta^j \frac{s_r}{\bar{s}_r} + \frac{1}{b_d} (1 - \zeta^j) \frac{s_d}{\bar{s}_d} \right) + (1 - \eta^j) \bar{s}_d \rho_d \left( \frac{\varepsilon^j}{b_r} \zeta^j \frac{s_r}{\bar{s}_r} + \frac{1}{b_d} (1 - \zeta^j) \frac{s_d}{\bar{s}_d} \right). \quad (\text{A41})$$

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 E, 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:

$$\pi^{LCP*}(\eta^j, \zeta^j) = \mathbb{E} \left[ s_i (p_i^{LCP})^{1-\theta} - \left( \frac{c(\eta^j, \zeta^j)}{\alpha} \right)^\alpha \left( \frac{w}{1-\alpha} \right)^{1-\alpha} (p_i^{LCP})^{-\theta} \right]. \quad (\text{A42})$$

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

$$p_i^{LCP} = \frac{\theta}{\theta-1} \frac{\mathbb{E} \left[ \left( \frac{c(\eta^j, \zeta^j)}{\alpha} \right)^\alpha \right]}{\mathbb{E} [s_i]} \left( \frac{w}{1-\alpha} \right)^{1-\alpha}. \quad (\text{A43})$$

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

$$\max_{\eta^j, \zeta^j} \left\{ \mathbb{E} \left[ \left( c(\eta^j, \zeta^j) \right)^\alpha \right]^{1-\theta} \right\}. \quad (\text{A44})$$

Therefore, using the definition of  $c(\cdot)$  in equation (A41), the firm will choose  $(\eta^j, \zeta^j) = (1, 1)$  over  $(\eta^j, \zeta^j) = (0, 0)$  if:

$$\mathbb{E} \left[ \left( \rho_r (\varepsilon^j / b_r) s_r \right)^\alpha \right] \leq \mathbb{E} \left[ \left( (\rho_d / b_d) s_d \right)^\alpha \right]. \quad (\text{A45})$$

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

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:

$$\mathbb{E} \left[ \left( \rho_r (\varepsilon^j / b_r) s_r \right)^\alpha \right] \leq \mathbb{E} \left[ \left( \tilde{s}_r (\rho_d / b_d) \frac{s_d}{\tilde{s}_d} \right)^\alpha \right]. \quad (\text{A46})$$

Using the log-normal distribution assumption:

$$\begin{aligned} \mathbb{E} [\varepsilon_j^\alpha] &\leq \left( \frac{\rho_d b_r}{\rho_r b_d} \right)^\alpha \frac{\mathbb{E} [s_d^\alpha \tilde{s}_d^{-\alpha} \tilde{s}_r^\alpha]}{\mathbb{E} [s_r^\alpha]} \\ &= \exp \left\{ \alpha(\mu_d - \mu_r) + \frac{\alpha^2}{2}(\sigma_d^2 - \sigma_r^2) + \alpha(\tilde{\mu}_r - \tilde{\mu}_d) + \frac{\alpha^2}{2}\sigma_{\tilde{r}}^2 + \frac{\alpha^2}{2}\sigma_{\tilde{d}}^2 - \alpha^2\sigma_{\tilde{r}\tilde{d}} - \alpha^2\sigma_{d\tilde{d}} + \alpha^2\sigma_{d\tilde{r}} \right\}. \end{aligned} \quad (\text{A47})$$

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

$$\mathbb{E} \left[ \varepsilon_j^\alpha \right] \leq \left( \frac{\rho_d b_r}{\rho_r b_d} \right)^\alpha \exp \left\{ \frac{\alpha^2}{2} \sigma_{\tilde{r}}^2 + \frac{\alpha^2}{2} \sigma_{\tilde{d}}^2 - \alpha^2 \sigma_{\tilde{r}\tilde{d}} + \alpha^2 (\sigma_{d\tilde{r}} - \sigma_{d\tilde{d}}) \right\}. \quad (\text{A48})$$

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

$$\sigma_{\tilde{r}}^2 + \sigma_{\tilde{d}}^2 - 2\sigma_{\tilde{r}\tilde{d}} + 2(\sigma_{d\tilde{r}} - \sigma_{d\tilde{d}}) \geq 0. \quad (\text{A49})$$

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

$$\text{Var}(\tilde{s}_r - \tilde{s}_d) + 2(\sigma_{d\tilde{r}} - \sigma_{d\tilde{d}}) \geq 0. \quad (\text{A50})$$

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:

$$\text{Var}(\tilde{s}_r - \tilde{s}_d) + 2(\sigma_{r\tilde{d}} - \sigma_{r\tilde{r}}) \geq 0. \quad (\text{A51})$$

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

$$\max_{\eta^j, \zeta^j} \left\{ \mathbb{E} \left[ \left( c(\eta^j, \zeta^j) \right)^\alpha s_i^\theta \right]^{1-\theta} \right\}, \quad (\text{A52})$$

and to the condition  $\mathbb{E} \left[ \varepsilon_j^\alpha \right] \leq \left( \frac{\rho_d b_r}{\rho_r b_d} \right)^\alpha \exp \{ \alpha \theta (\sigma_{id} - \sigma_{ir}) \}$  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:

$$\mathbb{E} \left[ \left( \rho_r (\varepsilon^j / b_r) s_r \right)^\alpha s_i^\theta \right] \leq \mathbb{E} \left[ \left( \tilde{s}_r (\rho_d / b_d) \frac{s_d}{\tilde{s}_d} \right)^\alpha s_i^\theta \right] \Leftrightarrow \quad (\text{A53})$$

$$\mathbb{E} \left[ \varepsilon_j^\alpha \right] \leq \left( \frac{\rho_d b_r}{\rho_r b_d} \right)^\alpha \frac{\mathbb{E}_0 \left[ s_d^\alpha \tilde{s}_d^{-\alpha} \tilde{s}_r^\alpha s_i^\theta \right]}{\mathbb{E}_0 \left[ s_r^\alpha s_i^\theta \right]} \quad (\text{A54})$$

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

$$\mathbb{E} \left[ \varepsilon_j^\alpha \right] \leq \left( \frac{\rho_d b_r}{\rho_r b_d} \right)^\alpha \exp \left\{ \frac{\alpha^2}{2} \sigma_{\tilde{r}}^2 + \frac{\alpha^2}{2} \sigma_{\tilde{d}}^2 - \alpha^2 \sigma_{\tilde{r}\tilde{d}} + \alpha^2 (\sigma_{d\tilde{r}} - \sigma_{d\tilde{d}}) + \alpha \theta (\sigma_{di} + \sigma_{i\tilde{r}} - \sigma_{ir} - \sigma_{i\tilde{d}}) \right\}. \quad (\text{A55})$$

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

$$\text{Var}(\tilde{s}_r - \tilde{s}_d) + 2(\sigma_{d\tilde{r}} - \sigma_{d\tilde{d}}) + \frac{2\theta}{\alpha} (\sigma_{i\tilde{r}} - \sigma_{i\tilde{d}}) \geq 0. \quad (\text{A56})$$

**The sufficient condition under RCP.** Now consider a firm acting under RCP. Assume that the condition  $\mathbb{E}_0 \left[ \varepsilon_j^\alpha \right] \leq \left( \frac{\rho_d b_r}{\rho_r b_d} \right)^\alpha \exp \{ \alpha \theta (\sigma_{id} - \sigma_{rd} - \sigma_{ir}) \}$  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 will choose  $\zeta^j = 1$  if:

$$\mathbb{E} \left[ \left( \rho_r (\varepsilon^j / b_r) \right)^\alpha (s_r)^{\alpha - \theta} (s_i)^\theta \right] \leq \mathbb{E} \left[ \left( \tilde{s}_r (\rho_d / b_d) \frac{s_d}{\tilde{s}_d} \right)^\alpha (s_r)^{-\theta} (s_i)^\theta \right] \Leftrightarrow \quad (\text{A57})$$

$$\mathbb{E} \left[ \varepsilon_j^\alpha \right] \leq \left( \frac{\rho_d b_r}{\rho_r b_d} \right)^\alpha \frac{\mathbb{E} \left[ (s_d)^\alpha (\tilde{s}_d)^{-\alpha} (\tilde{s}_r)^\alpha (s_i)^\theta (s_r)^{-\theta} \right]}{\mathbb{E} \left[ (s_r)^{\alpha - \theta} (s_i)^\theta \right]}. \quad (\text{A58})$$

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

$$\mathbb{E} \left[ \varepsilon_j^\alpha \right] < \left( \frac{\rho_d b_r}{\rho_r b_d} \right)^\alpha \times \exp \left\{ \frac{\alpha^2}{2} \sigma_{\tilde{r}}^2 + \frac{\alpha^2}{2} \sigma_{\tilde{d}}^2 - \alpha^2 \sigma_{\tilde{r}\tilde{d}} + \alpha^2 (\sigma_{d\tilde{r}} - \sigma_{d\tilde{d}}) + \alpha \theta (\sigma_{id} + \sigma_{i\tilde{r}} - \sigma_{i\tilde{d}} - \sigma_{ir}) - \alpha \theta (\sigma_{dr} + \sigma_{r\tilde{r}} - \sigma_{r\tilde{d}}) \right\}. \quad (\text{A59})$$

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

$$\sigma_{\tilde{r}}^2 + \sigma_{\tilde{d}}^2 - 2\sigma_{\tilde{r}\tilde{d}} + 2(\sigma_{d\tilde{r}} - \sigma_{d\tilde{d}}) + \frac{2\theta}{\alpha} (\sigma_{i\tilde{r}} - \sigma_{i\tilde{d}}) + \frac{2\theta}{\alpha} (\sigma_r^2 + \sigma_{r\tilde{d}} - \sigma_{r\tilde{r}}) \geq 0, \quad (\text{A60})$$

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:

$$\text{With LCP: } \text{Var}(\tilde{s}_r - \tilde{s}_d) + 2(\sigma_{d\tilde{r}} - \sigma_{d\tilde{d}}) \geq 0 \quad (\text{A61})$$

$$\text{With PCP: } \text{Var}(\tilde{s}_r - \tilde{s}_d) + 2(\sigma_{d\tilde{r}} - \sigma_{d\tilde{d}}) + \frac{2\theta}{\alpha}(\sigma_{i\tilde{r}} - \sigma_{i\tilde{d}}) \geq 0 \quad (\text{A62})$$

$$\text{With RCP: } \text{Var}(\tilde{s}_r - \tilde{s}_d) + 2(\sigma_{d\tilde{r}} - \sigma_{d\tilde{d}}) + \frac{2\theta}{\alpha}(\sigma_{i\tilde{r}} - \sigma_{i\tilde{d}}) + \frac{2\theta}{\alpha}(\sigma_r^2 + \sigma_{r\tilde{d}} - \sigma_{r\tilde{r}}) \geq 0 \quad (\text{A63})$$

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:

$$\sigma_{d\tilde{d}} = \sigma_{\tilde{d}}^2, \quad \sigma_{r\tilde{r}} = \sigma_{\tilde{r}}^2, \quad \sigma_{r\tilde{d}} = \sigma_{\tilde{r}\tilde{d}} = \sigma_{\tilde{r}\tilde{d}}. \quad (\text{A64})$$

Hence

$$\text{Var}(\tilde{s}_r - \tilde{s}_d) + 2(\sigma_{d\tilde{r}} - \sigma_{d\tilde{d}}) = \sigma_{\tilde{d}}^2 + \sigma_{\tilde{r}}^2 - 2\sigma_{\tilde{r}\tilde{d}} + 2(\sigma_{\tilde{r}\tilde{d}} - \sigma_{\tilde{d}}^2). \quad (\text{A65})$$

Under the assumption that  $\tilde{s}_d$  and  $\tilde{s}_r$  share the same marginal distribution, we have  $\sigma_{\tilde{d}}^2 + \sigma_{\tilde{r}}^2 - 2\sigma_{\tilde{r}\tilde{d}} = 0$ . 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  $(\eta^j, \zeta^j) = (0, 0)$  or  $(\eta^j, \zeta^j) = (1, 1)$  under PCP.

Last, under RCP, and since we assumed that  $\sigma_{i\tilde{r}} = \sigma_{i\tilde{d}}$ , the sufficient condition is  $\sigma_r^2 + \sigma_{r\tilde{d}} - \sigma_{r\tilde{r}} \geq 0$ . But  $\sigma_r^2 > \sigma_{r\tilde{r}}$ , 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.

## K Model extension: 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, where  $p_i^j$  is the price in

local currency units and  $q_i$  is the local demand shifter. Following Arkolakis et al. (2019), 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 third 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. It is useful to define  $\mathcal{S} = (\varepsilon^j, S, w, q, C)$  as 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.

**Proposition A2.** *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 still determined by thresholds  $\Phi$  and  $\Omega$  as in propositions 1 and 3.*
- (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 3.*

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.

## L Proof of proposition A2

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

$$\pi_i^{LCP}(p_i^j, \mathcal{S}) = [s_i p_i^j - C] Y \left( \frac{p_i^j}{q_i} \right). \quad (\text{A66})$$

Let  $p_i^{Fj}(\mathcal{S})$  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., 2019) that the optimal flexible price is, to the first order:

$$\hat{p}_i^{Fj} = (1 - \lambda) (\hat{c}^j - \hat{s}_i) + \lambda \hat{q}_i \quad (\text{A67})$$

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

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.

**Proof 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:

$$\hat{c}^j(1, \cdot) = \kappa_{1,w} w + \kappa_{1,r} s_r + \kappa_{1,\varepsilon^j} \varepsilon^j \quad (\text{A68})$$

The new parameters are defined as:

$$\kappa_{1,w} = \frac{\partial C}{\bar{w} \partial w}(1, \bar{\varepsilon}^j, \bar{S}, \bar{w}, \bar{q}), \quad \kappa_{1,r} = \frac{\partial C}{\bar{S}_r \partial S_r}(1, \bar{\varepsilon}^j, \bar{S}, \bar{w}, \bar{q}), \quad \kappa_{1,\varepsilon^j} = \frac{\partial C}{\bar{\varepsilon}^j \partial \varepsilon^j}(1, \bar{\varepsilon}^j, \bar{S}, \bar{w}, \bar{q}). \quad (\text{A69})$$

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

**Proof 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:

$$\pi_i^{LCP}(\hat{p}_i^j, \mathcal{S}) = \left[ \exp\{\hat{s}_i + \hat{p}_i^j\} - C^j \right] Y \left( \exp\{\hat{p}_i^j - \hat{q}_i\} \right), \quad (\text{A70})$$

$$\pi_i^{PCP}(\hat{p}_i^j, \mathcal{S}) = \left[ \exp\{\hat{s}_i + \hat{p}_i^j\} - C^j \right] Y \left( \exp\{\hat{p}_i^j - \hat{s}_i - \hat{q}_i\} \right). \quad (\text{A71})$$

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. For PCP, the point is:  $\hat{p}_i^{F,j} - \hat{s}_i$ .

From the definition of profit-maximizing prices:

$$\frac{\partial \pi^{PCP}(\hat{p}_i^{F,j} - \hat{s}_i, \mathcal{S})}{\partial \hat{p}_i^{F,j}} = \frac{\partial \pi^{LCP}(\hat{p}_i^{F,j}, \mathcal{S})}{\partial \hat{p}_i^{F,j}} = 0 \quad (\text{A72})$$

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:

$$\pi^{PCP}(\hat{p}_i^j; \mathcal{S}) - \pi^{LCP}(\hat{p}_i^j; \mathcal{S}) = \frac{1}{2} \frac{\partial^2 \pi^{LCP}(\hat{p}_i^{F,j}; \mathcal{S})}{\partial (\hat{p}_i^{F,j})^2} \left[ \left( \hat{p}_i^j - \hat{s}_i - \hat{p}_i^{F,j}(\mathcal{S}) \right)^2 - \left( \hat{p}_i^j - \hat{p}_i^{F,j}(\mathcal{S}) \right)^2 \right]. \quad (\text{A73})$$

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

$$\frac{\partial^2 \pi^{LCP}(\hat{p}_i^{F,j}; \mathcal{S})}{\partial (\hat{p}_i^{F,j})^2} = \frac{\partial^2 \pi^{LCP}(\hat{p}_i^{F,j}; \bar{\mathcal{S}})}{\partial (\hat{p}_i^{F,j})^2} + \mathcal{O}(\|\mathcal{S} - \bar{\mathcal{S}}\|) \quad (\text{A74})$$

Therefore, taking expectations of the previous expression one gets:

$$\mathbb{E} \left[ \pi^{PCP}(\hat{p}_i^j; \mathcal{S}) - \pi^{LCP}(\hat{p}_i^j; \mathcal{S}) \right] \approx \frac{1}{2} \frac{\partial^2 \pi^{LCP}(\hat{p}_i^{F,j}; \bar{\mathcal{S}})}{\partial (\hat{p}_i^{F,j})^2} \mathbb{E} \left[ \left( \hat{p}_i^j - \hat{s}_i - \hat{p}_i^{F,j}(\mathcal{S}) \right)^2 - \left( \hat{p}_i^j - \hat{p}_i^{F,j}(\mathcal{S}) \right)^2 \right]. \quad (\text{A75})$$



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

$$\mathbb{E} \left( \hat{p}_i^j - \hat{s}_i - \hat{p}_i^{F,j} \right)^2 \leq \mathbb{E} \left( \hat{p}_i^j - \hat{p}_i^{F,j} \right)^2. \quad (\text{A76})$$

Using equation (A67), this becomes:

$$\mathbb{E} \left( (1 - \lambda) \left( \hat{c}^j \right) + \lambda \hat{q}_i + \lambda \hat{s}_i \right)^2 \leq \mathbb{E} \left( (1 - \lambda) \left( \hat{c}^j - \hat{s}_i \right) + \lambda \hat{q}_i \right)^2. \quad (\text{A77})$$

Expanding the expectations and rearranging gives

$$2\sigma_{ic}(1 - \lambda) + 2\lambda\sigma_{iq} \leq (1 - 2\lambda)\sigma_i^2. \quad (\text{A78})$$

We will make use of equation (A78) when comparing RCP to LCP below.

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

$$\pi_i^{RCP}(\hat{p}_i^j, \mathcal{S}) = \left[ \exp\{\hat{s}_r + \hat{p}_i^j\} - C^j \right] Y \left( \exp\{\hat{p}_i^j + \hat{s}_r - \hat{s}_i - \hat{q}_i\} \right). \quad (\text{A79})$$

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

$$\begin{aligned} & \mathbb{E} \left[ \pi^{RCP}(\hat{p}_i^j; \mathcal{S}) - \pi^{PCP}(\hat{p}_i^j; \mathcal{S}) \right] \approx \\ & \frac{1}{2} \frac{\partial^2 \pi^{PCP}(\hat{p}_i^{F,j}; \bar{\mathcal{S}})}{\partial \left( \hat{p}_i^{F,j} \right)^2} \mathbb{E} \left[ \left( \hat{p}_i^{P,j} + \hat{s}_r - \hat{s}_i - \hat{p}_i^{F,j}(\mathcal{S}) \right)^2 - \left( \hat{p}_i^j - \hat{p}_i^{F,j}(\mathcal{S}) \right)^2 \right]. \end{aligned} \quad (\text{A80})$$

Again combining with equation (A67), this becomes:

$$\mathbb{E} \left( (1 - \lambda) \hat{c}^j - \hat{s}_r + \lambda \hat{q}_i + \lambda \hat{s}_i \right)^2 \leq \mathbb{E} \left( (1 - \lambda) \hat{c}^j + \lambda \hat{q}_i + \lambda \hat{s}_i \right)^2. \quad (\text{A81})$$

Evaluating the expectations gives:

$$\frac{1}{2} \sigma_r^2 \leq (1 - \lambda) \sigma_{cr} + \lambda (\sigma_{qr} + \sigma_{ir}). \quad (\text{A82})$$

Now, marginal costs are in equation (A68). Therefore:  $\sigma_{cr} = \kappa_{1,r} \sigma_r^2 + \kappa_{1,w} \sigma_{rw}$ . There-

fore, the expression above becomes:

$$\frac{1}{2}\sigma_r^2 \leq (1 - \lambda) \left( \kappa_{1,r}\sigma_r^2 + \kappa_{1,w}\sigma_{rw} \right) + \lambda(\sigma_{qr} + \sigma_{ir}) \Leftrightarrow \quad (\text{A83})$$

$$\sigma_{rw} \geq \frac{1}{2(1 - \lambda)\kappa_{1,w}}\sigma_r^2 - \frac{\lambda}{(1 - \lambda)\kappa_{1,w}}(\sigma_{qr} + \sigma_{ir}) - \frac{\kappa_{1,r}}{\kappa_{1,w}}\sigma_r^2. \quad (\text{A84})$$

This threshold is just like the one in proposition 3(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 proposition.

**Proof of proposition part (a): the  $\Phi$  threshold.** Inspecting equation (A79), 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 (A78). So the condition for choosing RCP over LCP is:

$$\sigma_i^2 \geq \frac{1}{(1 - 2\lambda)} \left[ \sigma_r^2 - 2(1 - \lambda)\sigma_{cr} - 2\lambda(1 - \lambda)(\sigma_{qr} + \sigma_{ir}) + 2\sigma_{ic}(1 - \lambda) + 2\lambda\sigma_{iq} \right]. \quad (\text{A85})$$

This threshold is just like the one in proposition 1(c). Again, when  $\lambda = 0$  and the production function is Cobb-Douglas so  $\kappa_{1,r} = \alpha$  and  $\kappa_{1,w} = 1 - \alpha$ , then the condition above simplifies to the one defined in the proposition.

**Proof of proposition part (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 (A85) with respect to  $\lambda$  is given by

$$\frac{2}{(1 - 2\lambda)^2} \left[ 2(\sigma_{cr} - \sigma_{ic}) - 2(1 - 2\lambda)(\sigma_{qr} + \sigma_{ir}) + 2\sigma_{iq} \right] \quad (\text{A86})$$

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 part (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 D, that the profits of the firm are given

by equation (A13), repeated here for convenience:

$$\begin{aligned}\Pi^j(\eta^j) &= \int_{\Delta^{LCP}(\eta^j)} \pi_i^{LCP*}(\eta^j) di + \int_{\Delta^{PCP}(\eta^j)} \pi_i^{PCP*}(\eta^j) di + \int_{\Delta^{RCP}(\eta^j)} \pi_i^{RCP*}(\eta^j) di \\ &\quad + \int_{\Delta^{DCP}(\eta^j)} \pi_i^{DCP*} di + \delta_r \pi_0^{RCP*}(\eta^j) + \delta_d \pi_1^{DCP*}(\eta^j)\end{aligned}$$

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

$$\pi_i^{\mathcal{P}*}(1, \varepsilon^j, S, w, q) - \pi_i^{\mathcal{P}*}(0, \varepsilon^j, S, w, q) \tag{A87}$$

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.

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.

Table A2: The effect of the swap lines on the prob. the RMB is used: Two way fixed effects estimator

	No controls (1)	Time & Seasonal f.e. (2)	Incl. Neigh. Share (3)	Incl. China Trade (4)	Incl. China Policy (5)
SwapLine Agreement <sub><i>i,t</i></sub>	0.2807*** (0.069)	0.1436** (0.070)	0.1406** (0.071)	0.1420** (0.070)	0.1406** (0.071)
Country f.e.	Yes	No	No	No	No
Country × Seasonal f.e.	No	Yes	Yes	Yes	Yes
Time f.e.	No	Yes	Yes	Yes	Yes
Neighbor Use Control	No	No	Yes	Yes	Yes
China Trade Controls	No	No	No	Yes	Yes
China Policy Controls	No	No	No	No	Yes
Observations	12804	12804	12804	12804	12804

Standard errors clustered by time and country in parentheses, \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Notes: Estimates of equation 1 using a two-way fixed effects estimator. Sample covers 132 countries over the period October 2010 to October 2018. For consistency with the baseline estimates the always treated observations are dropped. The outcome variable 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 Use<sub>*i,t*</sub> 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 presence of an RMB clearing bank and Chinese investment flows into the country.

Table A3: The effect of the swaplines: including developed economies

	all countries		just developed	
	f.e. only (1)	all controls (2)	f.e. only (3)	all controls (4)
SwapLine <sub><i>i,t</i></sub>	0.0100*** (0.04)	0.1078*** (0.040)	-0.0277 (0.047)	0.0068 (0.047)
Neighbour Use <sub><i>i,t</i></sub>		0.0287 (0.062)		-0.0557 (0.125)
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	15480		2676	
Number of Countries	160		28	

S.E. clustered by country and time in parentheses, \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Notes: Estimates of equation 1 using the Sun and Abraham (2021) methodology, never treated countries are the control group. Sample covers 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 (SwapLine<sub>*i,t*</sub>). Odd-numbered columns include time and country-calendar month fixed effects only. Even-numbered columns additionally includes as controls Neighbor Use<sub>*i,t*</sub>, China trade flows and an FTA dummy, and dummies for membership of the AIIB and the presence of an RMB clearing bank and Chinese investment flows into the country. Columns (1)-(2): Use a broader sample of a 160 countries including those with an average GDP per capita greater than \$30,000. Columns (3)-(4): Uses a narrow sample of only developed economies with per capita income greater than \$30,000

Table A4: The effect of the swaplines: different payment types

	payments rec'd		payments sent		trade credit (MT 400 and 700)	
	f.e.	all	f.e.	all	f.e.	all
	only	controls	only	controls	only	controls
	(1)	(2)	(3)	(4)	(5)	(6)
SwapLine <sub><i>i,t</i></sub>	0.1403*** (0.044)	0.1501*** (0.042)	0.1416*** (0.044)	0.1513*** (0.042)	0.1474*** (0.011)	0.1217*** (0.017)
Country f.e.	No	No	No	No	No	No
Country × Seasonal f.e.	Yes	Yes	Yes	Yes	Yes	Yes
Time f.e.	Yes	Yes	Yes	Yes	Yes	Yes
Neighbor Use Control	No	Yes	No	Yes	No	Yes
China Trade Controls	No	Yes	No	Yes	No	Yes
China Policy Controls	No	Yes	No	Yes	No	Yes
Observations	12804	12804	12804	12804	12804	12804

S.E. clustered by country and time in parentheses, \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Notes: Estimates of equation 1 using the Sun and Abraham (2021) methodology; never treated countries are the control group. Sample covers 132 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 (SwapLine<sub>*i,t*</sub>). Odd-numbered columns include time and country-calendar month fixed effects only. Even-numbered columns additionally includes as controls Neighbor Use<sub>*i,t*</sub>, China trade flows and an FTA dummy, and dummies for membership of the AIB and the presence of an RMB clearing bank and Chinese investment flows into the country. Columns (1)-(2): The outcome variable 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): as previous, but whether the country sent rather than received a payment. Columns (5)-(6): The outcome variable is an indicator variable for whether the country sent or received a RMB denominated SWIFT message type MT 400 or MT 700.

Table A5: The effect of the swaplines: heterogenous responses using split sample estimator

	Chinese Trade Share			Price Covariance			Intermediate Imports Share			Export Working Capital Needs		
	low	medium	high	low	medium	high	low	medium	high	low	medium	high
SwapLine <sub><i>t</i></sub>	0.0721 (0.043)	0.1145*** (0.047)	0.1474*** (0.076)	0.0414 (0.048)	0.1343 (0.093)	0.1479* (0.079)	-0.0738** (0.033)	0.2334*** (0.039)	0.1469*** (0.074)	-0.0819** (0.037)	0.1492*** (0.037)	0.1231** (0.041)
Country f.e.	No	No	No	No	No	No	No	No	No	No	No	No
Country × Seasonal f.e.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time f.e.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Neighbor Use	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
China Trade Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
China Policy Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,268	4,268	4,268	1,455	1,455	1,455	4,268	4,268	4,268	4,268	4,268	4,268
Number of Countries	44	44	44	15	15	15	44	44	44	44	44	44

S.E. clustered by country and time in parentheses, \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Notes: Estimates of equation 1 with SwapLine<sub>*t*</sub>, using the Sun and Abraham (2021) methodology; last treated country is the control group. The sample is divided based on country characteristics. Columns (1)-(3): Splits the sample depending whether the country is in the lower, middle or upper tertile of sample trade with China (each column correspond to a single regression). Columns (4)-(6) repeats the exercise sorting countries into tertiles based on the correlation between country i's RMB exchange rate and its PPI inflation rate. Correlations are computed in terms of 12 month growth rates over the sample. Limited availability of PPI data means that the sample covers 46 countries over the period October 2010 to October 2018. Columns (7)-(9) repeats the exercise for the intermediate import share and columns (10)-(12) for the working capital of exports. See A for exact definitions of these variables. All specifications include the complete control set: neighbor use, China trade and investment flows, and dummies for membership of the AIIB, a FTA with China and the presence of an RMB clearing bank.