Currency Invoicing, Trade Credit and Sudden Stops

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Abstract

When normal bank loans are scarce, supplier credit, or *trade credit*, can provide firms with much needed financing. We investigate the role of trade credit during a sudden stop (i.e. periods with rapid outflows of capital) and identify a new stylized fact. Trade credit flows out during a sudden stop, but only for those countries that invoice heavily in a foreign currency. We develop a theoretical model to provide intuition for the empirical results, and globally solve it. The model's framework follows in the style of a small open economy with a borrowing constraint, but we have the key innovation of a *second* occasionally binding constraint on the firm as they borrow and lend supplier credit. Importantly, our model reproduces the stylized fact. It also predicts that sudden stops happen much more often when trade is invoiced in a foreign currency. This also is consistent with the data, where we estimate that going from zero to all trade in domestic currency reduces the likelihood of being in a sudden stop.

1 Introduction

Payments for traded goods across borders are well behaved during tranquil times. Rarely exceeding a quarter percent of a country's GDP, these inflows and outflows balance each other well. Naturally, a global financial crisis can change this behavior, and in the wake of the most recent one, the literature on trade credit has exploded with research on the linkages between trade and financial constraints. Some consensus has emerged on what that role is: access to finance is especially important for importing and exporting firms because shipping goods across borders is costly and risky. Payments for exported goods are significantly delayed after shipment, and often even long after arrival. Importers that purchase goods from abroad likewise feel the crunch. Distributing, stocking and selling imported goods may take upwards of a month, and when this is combined with delays for invoicing and payments, trading firms often wait up to a full quarter until all payments are settled.(Amiti & Weinstein, 2011).

To bridge the time between paying for inputs and being paid by customers, firms have recourse to several forms of credit. Bank loans for this purpose are called *trade finance*, while loans directly from the supplier, often informal ones that show up in accounts payable and receivable, are called *trade credit* and are more common in terms of stocks and volume. For smaller firms in emerging markets, stocks of trade credit are nearly 30% of average revenues, and accounts payable/receivable dominates other forms of trade related financing (Schmidt-Eisenlohr, 2013).

Understanding of this form of finance has improved markedly after the Global Financial Crisis. But a global crisis is an especially unusual event during which most or all institutions and firms are in some way financially constrained. Crises that economists may see more often are highly localized. This paper aims at understanding the behavior of trade credit during the far more common, albeit still rare, sudden stop events. Sudden stops are defined as large unexpected outflows of capital from a country. In this paper we ask: *during a sudden stop, does trade credit provide an alternative source of financing*?

From the data, we show how countries with more trade in a foreign currency tend to lose access to trade credit during a sudden stop. The reverse is true when trade is invoiced in the home currency. To provide intuition for this result, this paper builds on a canonical framework of sudden stops following Mendoza (2010).[1] The key ingredient to replicating the data is a trading firm that is subject to a separate constraint, imposed by their foreign counterpart, on the firm's value function as in Gertler and Karadi (2011). In the context of a sudden stop, when output falls and real exchange rates depreciate, this added constraint will bind more tightly for firms that invoice in a foreign currency. On average, firms with tighter constraints import less, earn less income, and will exhibit higher volatility of import demand. This volatility is passed onto the household, so that in the end, the frequency of sudden stops is higher for a small open economy (SOE) that invoices more in a foreign currency.

The currency of invoicing plays a crucial role in the model. The results turn on the fact that the real exchange rate depreciates during a sudden stop. Because a firm's net assets are denominated in the home consumption good, while imported goods are purchased in foreign currency, a real exchange rate depreciation will reduce next period's value of net assets. This will lower the return from importing, raising the relative return from paying off supplier credit. Therefore the firm moves its resources away from buying new imports towards paying off old debts. Because these imports are used in intermediate production, a drop in imports further lowers domestic production and consumption.

As with the canonical sudden stop model of Mendoza (2010), our model matches the basic qualitative features of such events. Most importantly, output, consumption and the price of capital all fall sharply during the event, while net exports increase and the real exchange rate

[1] Similar frameworks are used in Durdu (2009), Korinek and Mendoza (2014), Bianchi (2011), Mendoza and Smith (2006) and Mendoza, Quadrini, and RíosRull (2009).

depreciates. One step beyond these results, we also match our stylized fact: that trade credit flows out of the country on average during a sudden stop, but less so when trade credit is denominated in a home currency.

This paper is most related to the literature that links financial frictions and trade flows. Amiti and Weinstein (2011) establish that bank health and trade finance is an important determinant for firm-level exports during crisis. Chor and Manova (2012) found that financially vulnerable sectors experienced a drop in monthly exports to the U.S. during the Global Financial Crisis. Feenstra, Li, and Yu (2014) find that it matters if goods are shipped domestically or internationally because of the time delay. Conditional on the firm's customers, a bank loan will be riskier and have a higher probability of default if the loan is made to a firm that trades internationally. On the other side of the argument, Levchenko, Lewis, and Tesar (2010) argue that at least in the most recent crisis, the trade credit mechanism had no significant effect on trade.

To identify the sudden stops in the data, this paper follows Calvo, Izquierdo, and Talvi (2003) by using a proxy for monthly net capital outflows. For robustness, we also use two measures of gross capital flows as in Forbes and Warnock (2011). Qualitatively our results change little between the methods for identifying the events. In the Appendix, Table 12 provides summary statistics for each of the types of sudden stops defined. Our empirical results will use Calvo's definition, however, reassuringly we'll see the results change little between definitions used. Table 8 in the Appendix provides a full list of all the sudden stops identified and used for this paper.

This paper proceeds by first describing the data set on invoicing currency used in the empirical analysis. Then we discuss the stylized facts from the sample of sudden stops and we introduce the model. Upon calibrating the model to the data, we explain the results and derive formal intuition behind the numerical simulations of the model.

1.1 Data on Currency

We take a moment to discuss the data on currency of invoicing used in this paper. Principally, Gopinath (2016) provides key data on the average share of imports and exports invoiced in foreign currency per country, with coverage of over 40 importing and exporting countries, and average shares over a mixed span of time. As Gopinath (2016) points out, and as other authors have noted in the literature (Ito and Chinn (2013) and Goldberg and Tille (2016)), the share of trade invoiced in foreign currency changes little from year to year, so that cross-period averages are a good measure.

For robustness, this papers takes a few steps to diversify the data set on currency beyond what is available in Gopinath (2016). First, we root out the annual data available on currency invoicing from national bank's publications, then interpolate between missing years from 1990 to 2018. These efforts are carefully documented and the sources of the data are reported in Table 7 in the Appendix. As the data are often spotty and available only annually for a small subset of our full sample of countries, we are modest about its usefulness

Second, we use the data set from SWIFT[2] on the currency of invoicing for transactions in Letters of Credit (LOC). LOCs are short term, bank-intermediated trade credit transactions between an exporter and importer. Although it is a proprietary source, the data appears often in the empirical literature on invoicing (e.g. Schmidt-Eisenlohr (2013)). It is available at a monthly frequency with the U.S. dollar value, origin, destination, and currency denomination for all transactions from 2010 until 2015[3]. The data set easily covers every country used in our sample over those years, and we include it as a supplemental measure of the currency of invoicing in our robustness checks in Table 10.

The main drawback to SWIFT data as a measure of currency invoicing is that only around 7% of the world's trade uses LOCs, with reportedly most of those transactions happening in emerging/middle income countries. If our goal is to broadly characterize the risk to firms' balance sheets due to trade credit during crises, this measure is incomplete. Also in a strict sense, LOCs are not supplier/seller credit in the way bank loans are bank-credit. LOC transactions do not appear in the Balance of Payments unless they are used as collateral with a bank for working capital.[4] Because LOCs are settled once the good has arrived, the life of the document is the transit time of the shipment from the seller to the buyer. This is in stark contrast to Open Account[5] or Cash-in-Advance trade credit that is used most often, wherein the firm pays late or early for the shipped good, usually several months in either direction.

Table 1: Summary of Currency Invoicing Shares (Percent)

Currencies	Trade with Letters of Credit	Total Trade
Total	6.67	100
Home Currency	7.54	38.08
Foreign Currency	92.46	61.92
U.S. Dollar	88.75	52.45
Euro	5.62	28.03

Source: SWIFT and supplemental data described in Table 7

[2]Data relating to SWIFT messaging flows is published with the permission of S.W.I.F.T. SCRL. SWIFT © 2018. All rights reserved.

[3]Before 2010, only the number of transactions are available.

[4]For a discussion and definition, see 5.13 of the BPM6 from the IMF.

[5]For more on these forms of trade credit, see Schmidt-Eisenlohr (2013), Hoefele, Schmidt-Eisenlohr, and Yu (2016) and Niepmann and Schmidt-Eisenlohr (2017b).

In our data set, about one third (71 of 206) of the sudden stops happen in the time periods between 2010 and 2015, which is the coverage of the SWIFT data set with currency information. We present a summary breakdown of the average currency composition of trade for the period of time covered by SWIFT. These averages are reported as a share of total trade (goods and services). The two data sets are qualitatively similar, with foreign currency invoicing dominating most of the world trade, and the U.S. dollar clearly being the one used principally.

1.2 Stylized Facts From the Sample

In this section, we draw out several well-established stylized facts about sudden stops, and argue that our *new* fact on the behavior of trade credit is robust. This part of the paper proceeds in two parts. First, we de-trend, filter and average the data for each country around their sudden stop events, and report general characteristics about macro-economic aggregates. Then, we bear down on the behavior of trade credit during these events, controlling for currency of invoicing by using a two-way fixed effects regression.

The behavior surrounding sudden stops in our data set are plotted below in Figure 1 for several macro-economic aggregates. Real exchange rates depreciates quickly in the lead up and period of the event. Real output and GDP fall, and net exports rise sharply, partly as a result of the depreciation in the real exchange, and partly from a decrease in home relative to foreign demand. As demand lags and production declines, *Tobins q* falls too[6], proxied by a composite index of equity prices.

Data on the stock index is an equity price index available from IFS. The GDP data are real quarterly statistics, and the real exchange rate data are real effective exchange rates by the consumer price index, again from IFS. Finally, data on the net exports are taken from the IMF's Balance of Payments database, and the figure here is calculated as the trade balance divided by total trade, or rather, exports minus imports over exports plus imports. Then we calculate the year over year log difference of the quarterly values for each series, multiplied by 100 and HP-filtered at 1600 to leave the cyclical component. We then take the mean and median across all countries with available data so that the data set is unbalanced but includes 44 countries. This procedure follows closely Korinek and Mendoza (2014), and Mendoza (2010).

Without micro-level data on firm-to-firm balances, the next best source of data on trade credit is the Balance of Payments (BOP) item, 'Trade Credits and Advances' that is available quarterly for most countries world wide (the sample for this variable has over 4000 country-year observations). In the most recent iteration of the BOP definitions (BPM6), the item is defined

[6]The ratio of the market value of capital relative to the replacement cost of capital.

Figure 1: General Characteristics

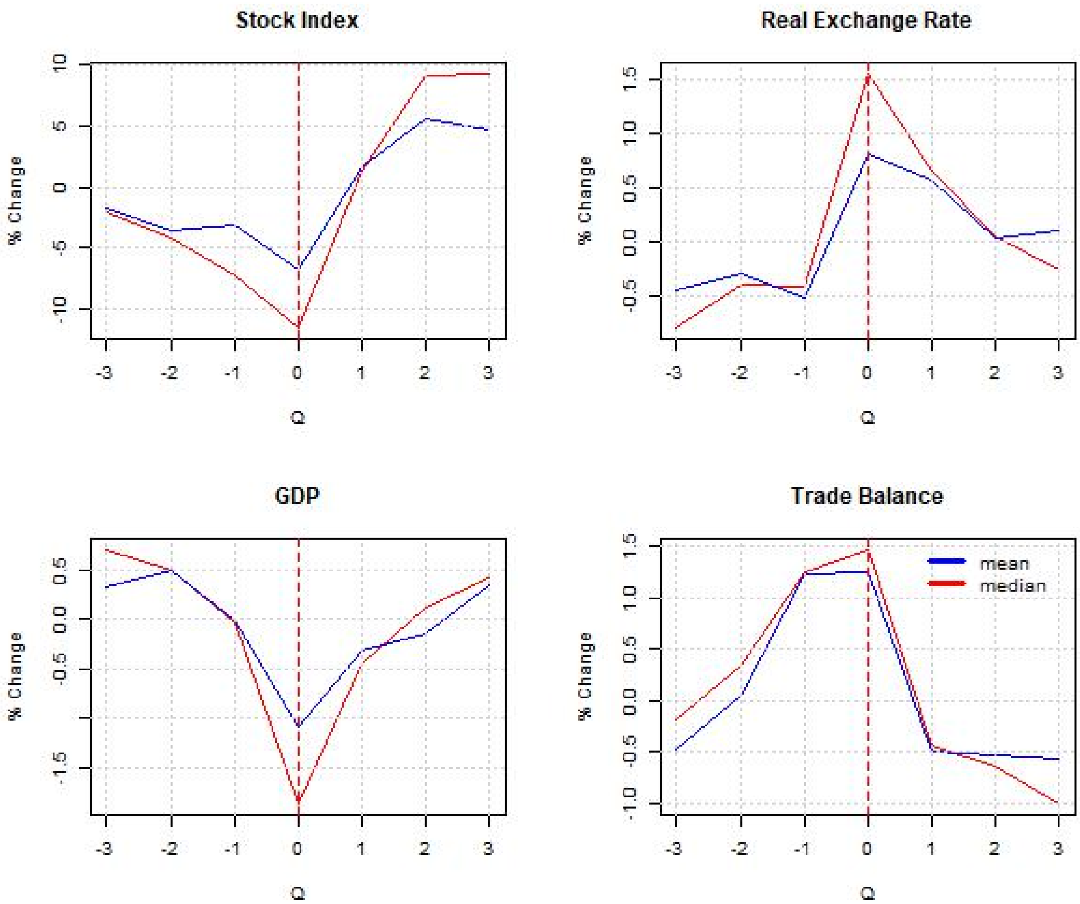


Figure 2: Capital Outflows / Imports

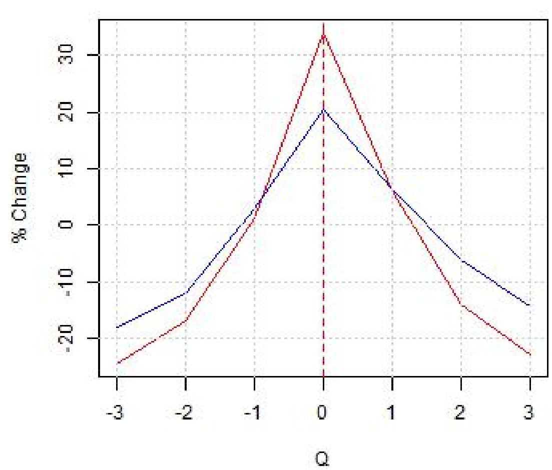


Figure 3: **Trade Credit Outflows / Imports**

(a) Countries with Foreign Invoicing (b) Countries with Home Invoicing

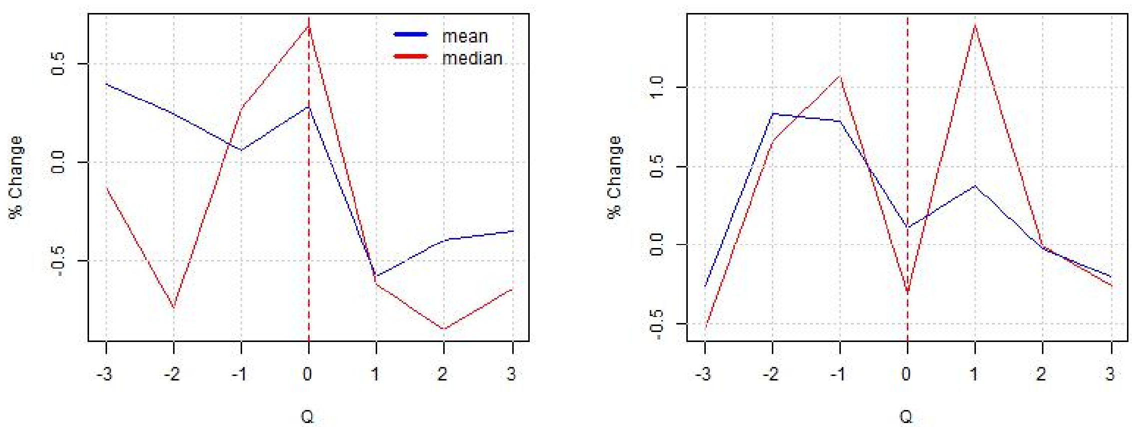


Figure 4

as the difference in value between the goods or services delivered and the amount paid for those goods. We avoid using the broader category 'Accounts Payable and Receivable' because it is less suitable to our question. It includes cross-border tax obligations, pending legal settlements, fines, etc., and other things that are not directly related to the cross-border shipment of goods.

Following Nilsen (2002), we scale trade credit by total imports to control for the size of the external sector of the economy.[7] Figure 3 splits the sample of 44 countries into two bins at the median home invoicing share of 0.31. That is, the 22 countries with up to 31% of their imports invoiced in a foreign currency are plotted on the left, and the remaining countries with higher than 31% are plotted on the right. Strikingly, moving from left to right, the direction of flows are reversed during a sudden stop. From peak to trough, the reversals are about 1% of imports, or about 1/2% of GDP on average.

Naturally our sample exhibits variation: not every sudden stop has all of the characteristics discussed above. For example, Brazil's crisis in the mid 1990's registered a decline in GDP of over 6% compared to the mean in our sample of 1.02%. There are two events for the United States (one in early the 1990s and the other being the Global Financial Crisis), that are technically sudden stops, even though the real and nominal exchange rates appreciated. Anomalies like this are well documented for the U.S. Dollar (Gourinchas, Rey, Govillot, et al., 2010), but it speaks to the point that these stylized facts are *generally* associated with sudden stop crises, even though there is natural variation across countries.

[7]We also run all results by scaling by imports plus exports, but there not a significant change in the results. This is not surprising give the high degree of correlation between imports and exports in the data.

The plots of in Figure 3 depict a clear relationship between the currency of invoicing and the direction of trade-credit flow during a sudden stop. However, an astute reader will point out that the share of imports in home currency is strongly correlated with a slew of other variables measuring a country's net and gross assets in a foreign currency, and these are, in turn, linked to the severity of a sudden stop. For instance, Gopinath and Stein (2018) highlights this concern about endogeneity whey the authors point out that dollar invoiced imports will lead to local investors demanding a larger share of assets in dollars, leading eventually to a higher degree of dollarization in both trade invoicing and liabilities. To mitigate some of this endogeneity, we test that the pattern of invoicing flows are robust to a host of controls for financial sector fragility, trade composition, etc.

The two-way fixed effects regression in (1) indexes i countries and t quarters for our unbalanced data set of 45 countries since 1990. In this regression, y_{it} is the share of net trade credit assets to imports, the regressors α_i are the country fixed effects, γ_t are time dummies for each quarter of the sample period, and ϵ_{it} is the normally distributed error per country and per quarter.

$$y_{it} = \alpha_i + \gamma_t + X_{it}\boldsymbol{\beta} + \sum_{k \geq -m}^{m} D_{it}^{k}\lambda^{k} + HM_i * \sum_{k \geq -m}^{m} D_{it}^{k}\kappa^{k} + \epsilon_{it} \tag{1}$$

The dummy variable D_{it}^k is 1 for country i at k periods from the occurrence of a sudden stop. HM_i is the share of trade invoiced in home currency per country, and is included as an interaction term for the dummy variables in D_{it}^k. The estimated coefficient λ^k is then the effect of a sudden stop on the ratio of trade credit to imports k quarters from event, when all trade is invoiced in foreign currency. The other key estimated coefficient, κ^k, is then the additional effect on trade credit flows arising solely from home currency invoicing. The index follows $k = -m, -(m-1), ..., 0, 1, 2, ...$, and we set $m = 3$.

Results from this regression are presented in the last two columns of Table 2. The first two columns of that table report the regression results without the HM_i-interaction term. Recall that invoicing measures are averages per country across time, so that the coefficient on HM_i is not separately identifiable from the country fixed effects. However, the interaction with the sudden stop dummies *are* identified, and will yield the marginal change in outflows arising from a 1 percentage point increase in share of trade invoiced in home currency. Looking to the results, trade credit flows out of the country during the sudden stop, amounting to almost 2% of imports, or roughly 1% of GDP.

In the set of auxiliary regressors X_{it}, ERA_t is included to control for 'Exchange Rate Arrangements' as defined in Ilzetzki, Reinhart, and Rogoff (2017). The goal is to reduce distortions from odd scenarios where currencies go through major upheavals, such as with the creation of the Euro Area, when suddenly large blocks of countries found themselves invoicing and trading

Table 2: Regression 1 Results

	Dependent variable:			
	100∗Net Flow of Trade Credit / Imports			
	(1)	(2)	(3)	(4)
$SuddenStop(t=0)$	0.934***	0.565***	1.825***	1.889***
	(−0.013)	(−0.070)	(−0.011)	(0.016)
$SuddenStop(t=0) * HM_i$			−2.571***	−3.564***
			(0.025)	(−0.180)
$ERA_t = FreeFalling$		12.934***		12.101***
		(−0.843)		(−0.908)
NFA_{t-1}		−0.953***		−0.996***
		(0.302)		(0.296)
$MANUF_{t-1}$		−2.054		−2.223
		(−4.833)		(−4.830)
Observations	2,609	1,646	2,609	1,646
R^2	0.176	0.232	0.180	0.241
Adjusted R^2	0.119	0.157	0.120	0.163

Note: *p<0.1; **p<0.05; ***p<0.01. All regressions include country fixed effects and time period dummies (quarterly).

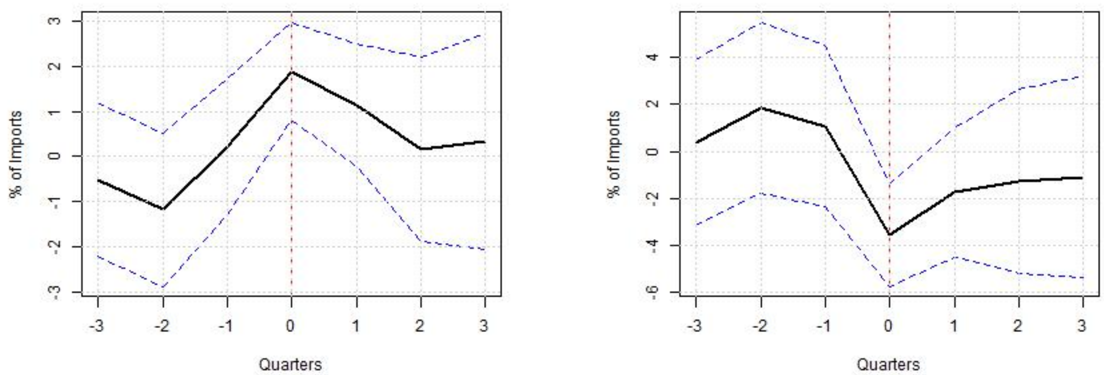
quite differently. In this variable there are five categories of regime with one being the most restrictive, and five being the least. For ease, and because it encompass the most countries, we only report the coefficient for the exchange rate category that is the least restrictive, i.e. a free falling currency.

NFA_{t-1} are Net Foreign Assets pulled from Bénétrix, Lane, and Shambaugh (2015), and calculated as the lagged ratio of total net foreign assets in a foreign currency divided by the sum of foreign assets and foreign liabilities. Our rationale for including this variable is the following: fewer net foreign assets are correlated with higher degrees of dollarization, and deeper recessions (Calvo et al. (2003) and Calvo, Izquierdo, and Mejía (2004)). If a country moves towards dollar-denominated debt over time and experiences deeper sudden stop recessions, and then has more extreme outflows of trade credit, this regressor will soak up that cross-country variation, hopefully reducing standard errors on the coefficients of interest ($\lambda^k and \kappa^k$).

$MANUF_{t-1}$ is the share of imports and exports of trade in goods to total imports and exports of goods and services. The goal is to control for the composition of a country's trade as it changes over time. The underlying assumption here follows from empirical evidence in Amiti and Weinstein (2011) that the long transit times associated with goods trade will raise demand for trade credit and a firm's exposure to risk. If this composition changes over time, country-level fixed effects will be insufficient, so this control will be necessary

Figure 5: **Estimated Trade Credit Outflows / Imports**

(a) Under Foreign Currency Invoicing (λ^k) (b) Under Home Currency Invoicing ($\lambda^k + \kappa^k$)



In the Appendix, Table 9 changes the definition of sudden stop from 'Net S.S.' to 'Gross S.S' and 'Flight.' Columns 1, 3 and 4 are re-run using these alternate definitions of sudden stops to hopefully show that overall results are robust to changes in definition of capital flight. Unfortunately the coefficients on the interaction term are no longer significant for Gross S.S., but the signs are always correct and the coefficients are on the same order of magnitude. The regression table (10) in the appendix uses multiple measures of currency, and interacts those definitions with several other regressors that may be correlated or similar to HM_i.

2 A Model of Trade Credit during a Sudden Stop

Consider a small open economy with a continuum of infinitely lived households that together have a mass of unity. Time is discrete ($t = 0, 1, 2, ..., \infty$) and each household consumes a final consumption good, supplies labor, and can invest in bonds or productive capital that is used by intermediate-goods firms.

Within each household, in every period, fraction φ of household members are owners of the trading firms and $1 - \varphi$ share of households are workers. Over time an agent can frictionlessly switch between the two roles. Agents stay firm owners into next period with probability ψ, and with probability $1 - \psi$ they revert back to supplying labor. The probability ψ is independent of history, so that in any period, fraction $\varphi(1 - \psi)$ of firm owners become workers again with an average survival time as firm owner of $1/(1 - \psi)$. Because there are the same shares of members leaving and entering each role, the proportion of firm owners to workers remains fixed. When agents leave the role as firm owner, they take with them a portion of the trading firms net assets, as we will describe in the next section. This initial setup of the agents in the economy follows a framework that has become common in the banking literature (e.g. Gertler and Karadi (2011) and Gertler and Kiyotaki (2010)).

The households' preferences over consumption (C_t) and labor supply (L_t) will be twice continuously differentiable and concave. The household is confronted with maximizing the lifetime value of utility,

$$E_0 \left\{ \sum_{t=0}^{\infty} \frac{\left(C_t - \eta \frac{L_t}{\omega}^{\omega}\right)^{1-\gamma}}{1-\gamma} \right\}. \tag{2}$$

where parameter γ corresponds to the coefficient of relative risk aversion, and ω is related to the Frische elasticity of labor, ψ^L, where $1/(\omega - 1) = \psi^L$. The parameter η is used later in calibrating the average level of L_t.

This form of preferences, first used in Greenwood et al. (1988), is employed in the macro-literature because it eliminates the wealth effect on labor supply, i.e. with theses preferences, when the worker is poorer they are not compelled to supply more labor. This will deepen the recession upon a drop in consumption, and lead to higher levels of volatility in consumption and investment. These preferences are also relatively common in the literature on sudden stops (see Mendoza (2010) and Korinek and Mendoza (2014)).

Final goods are produced by perfectly competitive producers that aggregate intermediate goods (from trading firms), and imported final goods from abroad. The final product, Z_t, is then sold to the home consumers and used for investment in capital I_t. Aggregation by these firms has a standard Constant Elasticity of Substitution (CES) form, with the degree of bias for the home intermediate good given by ϕ, and the elasticity of substitution between the imported and domestic goods given by ρ.

$$Z_t = \left(\phi^{1/\rho} x_t^{1-1/\rho} + (1-\phi)^{1/\rho} y_t^{1-1/\rho}\right)^{\rho/(\rho-1)}. \tag{3}$$

Upon minimizing costs, the final goods firm has demand functions for inputs of intermediate home goods x_t, and imported goods y_t. The standard results from the firm cost-minimization problem are firm demands for each of the products: $y_t = (1-\phi)\left(\frac{Q_t}{P_t}\right)^{-\rho} Z_t$ and $x_t = \phi\left(\frac{p_t^x}{P_t}\right)^{-\rho} Z_t$. The prices for x_t and y_t are respectively p_t^x and Q_t. Using these demands in the definition for final goods, we arrive at the price index $P_t = \left(\phi\,(Q_t)^{1-\rho} + (1-\phi)\,(p_t^x)^{1-\rho}\right)^{1/(1-\rho)}$. To simplify things, all prices are normalized by the final goods price, so that in what follows $P_t = 1$. The remaining prices in the economy are then relative to the price of the final good. Likewise, foreign prices are scaled by the domestic price index so that we define the real exchange rate as the ratio of the home and foreign price index, $Q_t = P_t^{\star}/P_t$, where the $(\star)$ indicates that a variable pertains to the foreign country. This paper will sometimes make an abuse of language and refer to prices in the home county relative to the home good as being in the home 'currency.' As there is no money in this model,[8] to write of 'currency' is not strictly accurate. The word, however, is intuitively clear and it will sometimes be expedient to use 'currency' as we explain the model and results.

The households can borrow or invest in a real bond from abroad (B_t) that will pay an interest rate next period of R_t in units of the foreign good. Capital is also available for purchase at price q_t from capital goods producers (described below), with a return next period of r_t^k. The households supply labor, L_t at the real wage rate W_t. Finally, households will receive any profits from final goods firms, capital producing firms, and the portion of net assets of trading firms that come from exiting firm owners. These payments arrive in lump-sum fashion in the amount of Π_t. All together households have the following budget constraint, with Lagrange multiplier λ_t,

$$C_t \leq W_t L_t - B_{t-1} Q_t R_{t-1} + B_t Q_t - q_t I_t + r_t^k K_{t-1} + \Pi_t. \tag{4}$$

New investment (I_t) in capital is defined as the change in the capital stock at the start of each period, where share δ of capital depreciates over time.

$$I_t = K_t - (1 - \delta) K_{t-1}. \tag{5}$$

Finally, households face a collateral constraint on new borrowing from abroad ($B_t Q_t$). Variations of this constraint appear throughout the sudden stops literature, largely because it is effective in generating a response in the model that closely mimics a sudden stop in the data. Roughly, it subjects borrowing to an upper limit as a fraction of total output. On the right side of the constraint is the total share of home country's income that is recoverable to the foreign country in case of default. Here κ represents the share of assets that can be recovered, however ζ share of the total wage bill is not recoverable. An ad-hoc justification for including this wage-bill component is to think of it as representing pay-day loans to households. When the sudden stop arrives, that portion of capital assets cannot be recovered because it is tied up in the household. The wage-bill component will be essential in generating a sudden stop in the period that the constraint binds.

On the left side of the constraint is new debt borrowed from abroad. The foreign lender, however, is only able to recover a portion of their loan if the value of their loan exceeds the endogenous threshold on the left side. Faced with the possibility of default, the constraint ensures that the home country cannot borrow above the amount of assets lost in default ($\kappa q_t K_t - \zeta W_t L_t$),

[8]There are no price frictions, cash-in-advance constraints, nor utility from real money balances, so that the price level in this model would be undefined if money were included.

and come away with an infinite source of income.

$$Q_t B_t \leq \kappa q_t K_t - \zeta W_t L_t \tag{6}$$

Here, μ_t is the Lagrange multiplier that will be weakly positive when the constraint binds. In these binding states, borrowing is limited and consumption falls. To relax the constraint, households are confronted with either investing more or working less to decrease the right side of the constraint. The prospect of working less will reduce the future return on capital, so that the incentive for investing and holding K_t will actually fall, dragging down the price of capital q_t. This clearly reduces the right side of the constraint, causing it to tighten further. Compounding this problem is that foreign lending is denominated in units of the foreign good. As consumption and q_t fall, the oversupply of domestic production causes the traded goods price p_t^x to drop also. This pushes up the real exchange rate, which drives up the current price of borrowing, and reduces B_t.

Having described the household's preferences and constraints, we are now ready to define the household optimization problem. Households choose C_t, L_t, B_t, and I_t to maximize their lifetime value of utility (2), subject to budget constraint (4), the definition of investment (5), and the collateral constraint on external borrowing (6). The first order conditions from this standard problem yield that the Langrange multiplier on the budget constraint (λ_t) is also positive and, $\lambda_t = \left(C_t - \eta \frac{L_t^\omega}{\omega}\right)^{-\sigma}$. Labor supplied will be chosen to satisfy the first order condition with respect to labor,

$$L_t = \left(\frac{W_t}{\eta}\left(1 - \frac{\mu_t}{\lambda_t}\zeta\right)\right)^{1/(\omega-1)}. \tag{7}$$

With $\omega > 1$, labor hours are increasing in the wage rate but decreasing in collateral constraint on borrowing μ_t. The Stochastic Discount Factor (SDF) is the ratio of next period and this period marginal utility of consumption: $\Omega_{t+1} = \frac{\lambda_{t+1}}{\lambda_t}$, so that from the first order condition on bonds

$$\frac{\mu_t}{\lambda_t} = 1 - R_t \beta E_t \left(\Omega_{t+1} \frac{Q_{t+1}}{Q_t}\right). \tag{8}$$

An increase in the exogenous foreign interest rate, R_t, must be met with an increase in λ_t, a decrease in μ_t, or a rise in the real exchange rate, Q_t. Finally, the condition for new capital investment is,

$$q_t \left(1 - \kappa \frac{\mu_t}{\lambda_t}\right) = \beta E_t \left(\Omega_{t+1} \left[q_{t+1}(1-\delta) + r_{t+1}^k\right]\right). \tag{9}$$

Note that when the constraint binds, there will be a wedge driven between the expected returns to capital and the returns from investing (or borrowing) from abroad. Using Equation 8 in 9,

$$\frac{1-\kappa}{R_t \beta E_t \left(\Omega_{t+1} \frac{Q_{t+1}}{Q_t}\right)} + \kappa = \frac{\beta E_t \left(\Omega_{t+1} \left[q_{t+1} (1-\delta) + r^k_{t+1}\right]\right)}{q_t R_t \beta E_t \left(\Omega_{t+1} \frac{Q_{t+1}}{Q_t}\right)} \tag{10}$$

In the unconstrained equilibrium ($\mu_t = 0$), future returns to capital and bonds are equal. However, when the constraint binds ($\mu_t > 0$), the expected returns to capital are increased because it now serves the added benefit of reducing the borrowing constraint. If the borrowing constraint (17) was just a function of the capital stock, this mechanism would spur an investment boom in the home country. Instead, because there is also the wage bill in the collateral constraint, the net effect on the returns to capital and investment is negative.

2.1 Capital Producers

At the end of each period, competitive producers buy capital from the households and create new capital, subject to adjustment costs. This capital is sold back to consumers at price q_t. The functional form for adjustment costs is

$$f(I_t, K_t) = \frac{\xi^\kappa}{2} \left(\frac{I_t}{\delta K_t} - 1\right)^2 \frac{\delta K_t}{I_t}.$$

where costs are proportional to the past capital stock[9] as in Dedola, Karadi, and Lombardo (2013) and Chari, Kehoe, and McGrattan (2002), and ξ^κ is used in calibration. The firm maximizes the lifetime value of firm profits,

$$\max_{I_t} \left\{\Omega_{t,t+1} \left[q_t I_t - I_t \left(1 + f(I_t, K_t)\right)\right]\right\}.$$

so that the competitive price of capital is $q_t = 1 + \xi^\kappa \left(\frac{I_t}{\delta K_t} - 1\right)$. All profits or losses are remitted back to the consumer in lump sum fashion (included in the term Π_t discussed above). These firms are still owned by the consumer, so that lifetime profits are discounted by the household's SDF, Ω_{t+1}.

[9] An added benefit of using this function form is we can save on computing time for the global solution by avoiding having lagged investment as a state variable.

2.2 Trading Firms

Trading goods firms are the driving force behind the trade credit dynamics in this model. At the *start* of each period, firms are confronted with a static profit maximization problem to choose inputs for production: labor, capital, and imported intermediate goods. Then, at the *end* of the period, trading firms are confronted with a second *dynamic* decision of how to allocate their net assets to maximize the lifetime value of the firm.

A firm's net assets will consist of two investments. First, trade credit (F_t) behaves like a standard one-period bond in that it yields a return next period. In contrast to the household's bond (B_t) however, trade credit is borrowed from the foreign firm and will have a fraction α of its value denominated in units of the home country's consumption good. Also, because trade credit is contracted with the firm rather than the household, the stochastic discounting factor that prices trade credit will be a function of the firm's net assets. This will play a key role in the behavior of trade credit during sudden stops.

Second, new orders of intermediate goods (y_t^I) will be placed (and paid for) in period t, but will not arrive until the following period. Upon using imports for production, the firm earns returns r_{t+1}^I that are competitively determined. Therefore the firm is subjected to risk from changes in demand over time, i.e. demand could be lower than expected in period $t+1$, reducing r_{t+1}^I and causing a net loss to the firm's net assets.

We start with the firm's static decision at the beginning of the period. Firms take as given the quantity of imported goods in the market (y_{t-1}^I) and the available stock of capital owned by the household (K_{t-1}). The household lends all their capital to the producing firm at a competitive rate r_t^k that will be equal to its marginal productivity. Firms combine y_{t-1}^I and K_{t-1} into a composite good (X_t) using a CES aggregator with elasticity of substitution σ, and weight on domestic capital given by ϱ. Total output of the traded good (Y_t) is then produced by combining X_t and L_t using a standard Cobb-Douglass production function. Stochastic technology shocks (θ_t) follow an exogenous process and hit output each period. All together, the firm is tasked with maximizing profits, subject to the definitions for the production function,

$$\max_{L_t, y_{t-1}, K_{t-1}} \left\{ p_t^x Y_t - r_t^I y_{t-1}^I - r_t^k K_{t-1} - W_t L_t \right\}$$

subject to:

$$X_t = \left(\varrho^{1/\sigma} \left(K_{t-1}\right)^{1-1/\sigma} + (1-\varrho)^{1/\sigma} \left(y_{t-1}^I\right)^{1-1/\sigma} \right)^{\sigma/(\sigma-1)}$$

$$Y_t = \theta_t X_t^\alpha L_t^{1-\alpha}$$

$$log\left(\theta_t\right) = log\left(\theta_{t-1}\right) \rho_\theta + \epsilon_{t,\theta}$$

and the technology shock follows a stochastic process with persistence ρ_θ and *iid* shocks $\epsilon_{t,\theta}$. Once the imported goods have entered the market at the beginning of period t, firms can freely trade amongst themselves stocks of imported goods at the competitive rate of return. Labor and capital are also traded freely so that y_t^I, K_t and L_t are each paid their marginal products in terms of the consumption good, respectively r_t^I, r_t^k, and W_t. Therefore,

$$
\begin{aligned}
r_t^I &= p_t^x \frac{\partial Y_t}{\partial y_{t-1}^I}, \\
r_t^k &= p_t^x \frac{\partial Y_t}{\partial K_{t-1}}, \\
W_t &= p_t^x \frac{\partial Y_t}{\partial L_t}
\end{aligned}
$$

At the end of each period, firms need to purchase intermediate inputs from abroad for next period. For this, the firm has net assets (N_t) they invest each period in new orders or they can lend supplier credit to their foreign counterpart in the amount F_t. If the firm starts the period with low net assets, they will have to pay for new orders 'on credit' and their trade credit F_t will be negative. Net assets are the sum of the firm's investments this period,

$$N_t = y_t^I Q_t + F_t. \tag{11}$$

Notice that there is no role for short term bank loans, or in the context of this model, the consumer cannot step in and provide loans to the firm. This is a limitation of the model, but it allows us to focus our attention on an under-explored mechanism. Certainly in the data, exporting and importing firms borrow from banks to help with purchases of new intermediate inputs. There is a robust literature on the role of bank finance in trade (see Chor and Manova (2012), Ahn, Amiti, and Weinstein (2011), Feenstra et al. (2014)) that has bloomed since the Global Financial Crisis. Our focus in this model is rather the firm-to-firm financing relationship, which empirically is at least as important as bank finance in terms of stocks of assets and liabilities (Nilsen, 2002).

We use a simple exogenous parameter, α, to determine the share of trade credit denominated in the home good. Firms also charge a fixed rate for credit, set at $\bar{R}^c$. This is both realistic and simplifying. In the literature around trade credit, most firms rarely, if ever, change the interest rate they charge suppliers, instead choosing a payment plan option that is common in their industry (Vaidya (2011) and Nilsen (2002)). For example, a common method of charging interest rates is to offer steep discounts when the bill is paid early. From research using survey data,[10] *2 10 net 30* is an often-used payment option signifying that if the bill is paid within 10 days, there is a 2% discount. Some authors have calculated average annualized interest rates on trade credit, following similar discount plans, to be upwards of 30% annually. We use this rate

[10] An example of a paper that cites survey data and reports this is (Love, Preve, & Sarria-Allende, 2007).

for $\bar{R}^c$ in the calibration of the model. Defining F_t^f as the amount of trade credit in units of the foreign good, and F_t^h as the amount in the home good,

$$Q_t F_t^f = F_t (1 - \alpha)$$
$$F_t^h = F_t \alpha$$

Letting R_t^c be the ex-post return on F_t, it is simple to show that the return will be a weighted average of the change in the real exchange rate and 1. Since this total return is just the sum of the returns on home and foreign trade credit next period,

$$R_t^c F_{t-1} = \left(Q_t F_{t-1}^f + F_{t-1}^h \right) \bar{R}^c \tag{12}$$

And then using our definitions for F_t^f and F_t^h, and simplifying,

$$R_t^c = \bar{R}^c \left((1 - \alpha) \frac{Q_t}{Q_{t-1}} + \alpha \right) \tag{13}$$

Each period then, the start-of-period net assets is the sum of returns on investments for imported inputs and trade credit. We move from the first to second line by substituting out F_t in (14) using (11)

$$N_t = y_{t-1}^I r_t^I + F_{t-1} R_t^c \tag{14}$$
$$= y_{t-1}^I Q_{t-1} \left(\frac{r_t^I}{Q_{t-1}} - R_t^c \right) + N_{t-1} R_t^c \tag{15}$$

We can now sum across all firm owners. Just as in Gertler and Karadi (2011), aggregating net assets across all agents is straightforward because production is constant returns to scale and factor prices are perfectly competitive. Also, recalling that only ψ share of all agents stay on as trading firm owners, only that portion of net assets moves on into the next period. Finally, we follow the literature by giving new firm owners start-up capital equal to the share ω^y of last periods' import orders. In the calibration, ω^y is small (on the order $1E-3$) and does not greatly influence the results, but is necessary to ensure that N_t is stationary in the numerical solution.

$$N_t = \left[y_{t-1}^I Q_{t-1} \underbrace{\left(\frac{r_t^I}{Q_{t-1}} - R_t^c \right)}_{\text{Return on Imports}} + N_{t-1} R_t^c \right] \psi + \omega^y y_{t-1} Q_{t-1} \tag{16}$$

Although trading firms can borrow from abroad, the foreign firm imposes a constraint on the trading firm, limiting the amount they can order to some share Γ of the firm's upcoming inventories, $y_t^I Q_t$. Similar to the household constraint in (17), this constraint on the firm is motivated by the foreign country's fear that the domestic firm will run away with assets while failing to repay debts. If the value of continuing the firm-to-firm relationship V_t falls below the value of assets the firm can abscond with next period, then the foreign firm will choose to either not lend or not sell so much to the trading firm. The home trading firm can abandon the relationship, default on their trade credit debt and walk away with Γ share of the purchased goods when they arrive next period, without paying anything to the foreign firm. They will do this, only when the value of doing so exceeds the value of staying a trading firm owner, which is V_t. This constraint can be written as,

$$V_t \geq \Gamma_t y_t^I Q_t \tag{17}$$

The firm is now confronted with choosing F_t and y_t^I to maximize the V_t, subject to the flow of net assets in (16), and their constraint on orders in (17). Future profits are discounted stochastically using the households stochastic discount factor Ω_{t+1}, and there is the probability $1-\psi$ that the firm owner exits unexpectedly tomorrow, taking with them N_{t+1}. There is also the probability ψ that they do not exit and continue to earn V_{t+1}. All together, the firms end-of-period maximization problem is

$$\begin{gathered} V_t = \max_{F_t^f,\, y_t^I} E_t \Omega_{t+1} \left\{ (1-\psi) N_{t+1} + \psi V_{t+1} \right\} \\ \text{subject to: (16) and (17)} \end{gathered} \tag{18}$$

The results from the firm's end-of-period maximization problem is given in Result 1 below, where we solve for V_t and χ_t (the Lagrange multiplier on the firms constraint (17))

Result 1. Solving the firm problem yields the value function as a sum of time varying coefficients v_t^I and v_t^n, multiplied by state variables $y_t^I Q_t$ and N_t

$$\begin{aligned} V_t &= v_t^I y_t^I Q_t + v_t^n N_t \\ &\text{with} \end{aligned} \tag{19}$$

$$v_t^I = E_t \left(\hat{\Omega}_{t+1} \left[\frac{r_{t+1}^I}{Q_t} - R_{t+1}^c \right] \right) \tag{20}$$

$$v_t^n = E_t \left(\hat{\Omega}_{t+1} R_{t+1}^c \right) \tag{21}$$

where the stochastic discount factor for the firm in these expressions is defined as

$$\hat{\Omega}_{t+1} = \Omega_{t+1}\left(1 - \psi + \psi\frac{\Gamma v^n_{t+1}}{\Gamma - v^I_{t+1}}\right) \tag{22}$$

Also, the value for the firms' Lagrange multiplier is

$$\chi_t = \frac{v^I_t}{\Gamma - v^I_t} \tag{23}$$

Proof. See Appendix A.

2.3 The Foreign Country

As is standard in small open economy models, the foreign country will determine the interest rate on bonds (R_t) and the demand for the home countries exports (x^I_t). Here we make an important assumption that keeps with the small open economy setup: the foreign country is unconstrained. That is, neither its firms nor households are subject to constraints that bind.

We let an exogenous process stand in for the foreign households' marginal utility, $\lambda^\star_t$ which follows an autoregressive process with persistence ρ_λ and subject to *iid* shocks $\epsilon_{t,\lambda}$.

$$log\left(\lambda^\star_t\right) = \rho_\lambda log\left(\lambda^\star_{t-1}\right) + \epsilon_{t,\lambda} \tag{24}$$

Supposing that the foreign consumer follows a similar optimization problem to the agents at home, then the standard Euler equation for bonds will give us an expression for the interest rate in terms of the foreign country marginal utility $\lambda^\star_t$

$$R_t = \frac{\lambda^\star_t}{\beta E_t\left(\lambda^\star_{t+1}\right)} \tag{25}$$

Given that the foreign firm is unconstrained, the firm's value for imported goods will again mirror Equation 20, but the value will always be zero[11].

$$v^{I,\star}_t = E_t\left(\hat{\Omega}^\star_{t+1}\left[r^{I,\star}_{t+1}Q_t - R^{c,\star}_{t+1}\right]\right) = 0 \tag{26}$$

[11]Note when the constraint does not bind in the home country, then $\mu_t = 0$ and $v^I_t = 0$. Supposing that the home and foreign countries have similarly defined firms, and that the foreign firm is unconstrained, we arrive at the result that $v^{I,\star}_t = 0$.

Rearranging this equation for $x^{\star}_t$ which is found within r^I_{t+1}, we arrive at

$$x^{\star}_t = \left(\frac{\zeta^{\star}_t}{Q_t}\right)^{-\sigma}$$
$$\text{with} \tag{27}$$
$$\zeta^{\star}_t = \frac{E_t\left(\hat{\Omega}^{\star}_{t+1} R^{c,\star}_{t+1}\right)}{E_t\left(\hat{\Omega}^{\star}_{t+1} \frac{Y^{\star}_{t+1}\alpha^{x,\star}}{X^{\star}_{t+1}} \left(\varrho^{\star} X^{\star}_{t+1}\right)^{1/\sigma^{\star}}\right)}.$$

Each variable with a $\star$ superscript refers to the foreign countries' analogously defined variable. Instead of modeling all the dynamics behind $\zeta^{\star}_t$, we let $\zeta^{\star}_t$ follow an exogenous autoregressive process with persistence ρ_{ζ} and subject to *iid* shocks $\epsilon_{t,\zeta}$. The long run value of this process is $\bar{\zeta}^{\star}$ which is used to calibrate the model to the data.

$$log\left(\zeta^{\star}_t\right) = \rho_{\zeta} log\left(\zeta^{\star}_{t-1}\right) + \left(1 - \rho_{\zeta}\right) log\left(\bar{\zeta}^{\star}\right) + \epsilon_{t,\zeta}$$

2.4 Market Clearing

Below, the first equations says that the market for final goods clears when all final goods output is used for consumption or investment. The second equations says that markets clear for intermediate goods when total trading firms' output is used in final consumption in the home country or in intermediate goods production abroad.

$$Z_t = C_t + I_t$$
$$Y_t = x_t + x^I_t$$

This concludes the setup for the baseline model. In the next few sections, we will calibrate the model, solve it globally and draw some intuitive results about the behavior of trade credit during a sudden stop. Finally, we will offer an extension where trading firms can choose the currency of invoicing subject to adjustment costs.

2.5 Numerical Solution Method

This section defines the solution for the model and describes generally how we arrived there. Much of the solution follows Judd, Maliar, and Maliar (2011), however, we implement a few innovations to handle the large state space and the presence of two occasionally binding constraints. In Appendix C, we provide a full explanation of the procedure.

The solution will be the series of endogenous and exogenous state variables, $\{s_t, z_t\}_{t=0,...,\infty}$, that together satisfy the system (28) and (29). These are together the set of first order conditions and relationships $\tilde{Z}(.)$ that define the transition of state variables from one period into the next. We let the function $Y(s_t, z_t) = y_t$ determine the static choice variables in time t. The state variables of the model are, $S_t = \{F_{t-1},\ Q_{t-1},\ K_{t-1},\ y^I_{t-1},\ B_{t-1}R_{t-1},\ \theta_{t-1},\ \zeta^\star_{t-1},\ \lambda^\star_{t-1}\}$, and the static choice variables are $y_t = \{C_t,\ y^I_t,\ x_t,\ F_t,\ B_t,\ Q_t,\ W_t,\ L_t,\ \chi^{Z1}_t,\ \chi^{Z2}_t\}$. The two choice variable, χ^{Z1}_t, χ^{Z2}_t are continuous versions of the discontinuous Lagrange multipliers, χ_t and μ_t. As we describe in the Appendix, we follow Zangwill and Garcia (1981) in making this replacement.

Here ϵ_t is the vector of exogenous shocks in this model. To get a starting point for the solution, we solve the model up to the second order in *Dynare* for each of the possible 'worlds' of the model, i.e. for each combination of the occasionally binding constraints: (1) $\chi_t > 0$, $\mu_t > 0$, (2) $\chi_t > 0$, and $\mu_t = 0$, (3) $\chi_t = 0$, $\mu_t > 0$ and (4) $\chi_t = 0$, $\mu_t = 0$. We then splice the solutions together following Maliar and Maliar (2015). This provides a full series of s_t and z_t, on which we calculate the starting values s_0 and z_0 as the averages of endogenous and exogenous variables from the spliced solution.

Using a 3rd degree polynomial and set of initial coefficients, we parameterize the policy functions $\hat{S}(s_t, z_{t+1}, b)$ that can be used as an approximation of the true policy function $S(s_t, z_{t+1})$. Here, b is a set of 2rd order polynomial coefficients and their basis functions. The goal is to solve for b in the $\hat{S}$ so that $\hat{S}(.) = S(.)\ \forall t$. In other words, we need to solve for b that satisfies (28) below.

$$0 = E_t\left(s_t, z_t, \hat{S}\left(x_t, z_{t+1}, b\right), z_{t+1}\right) \quad \forall t \tag{28}$$

$$z_{t+1} = \tilde{Z}\left(z_t, \epsilon_{t+1}\right) \tag{29}$$

To find b, we employ an iterative solution method as in Judd et al. (2011). The full solution method is described in the appendix, along with an assessment of the solutions' accuracy.

2.6 Calibration and Solution

Our goal in the calibration is to choose parameters so that the simulated model's results mimic as closely as possible the stylized facts around a sudden stop. In particular, we will use Simulated Method of Moments (SMM) (Duffie & Singleton, 1993) to choose the values for a subset of parameters so that the distance is minimized between the models simulated predictions and the real world data. This method will require solving the model repeatedly following Section 2.5, each time calculating a measure of distance between the simulated moments and the empirical ones, and then adjusting the subset of parameters in a direction that will likely reduce that distance. This process repeats until the distance between simulated and sample data reaches a minimum.[12]

All other parameters are pulled from the literature on sudden stops and other SOE models. The share of income going to capital, α, in the data hovers around 0.4. The Frische elasticity of labor supply is set to $\psi = 0.5$ as is standard in the literature. The consumer's discount factor β is set to match the long-run average quarterly real interest rate on U.S. treasury bonds. The elasticity of substitution for foreign intermediate inputs in production, σ, is set to 0.8, and we likewise set ρ in final consumption to 0.7 as it often is in the Sudden Stops literature. The share of foreign intermediate inputs, ϱ, is calibrated so that total income share of intermediate output going to imports is 1/4 which is approximately equal to world averages. The coefficient of relative risk aversion γ is set to the standard for long run macro-economic models with a value of 2. Labor parameter η is set so that $L_t = 1/3$ on average in the steady state of the unconstrained model (with $\mu = \chi = 0$).

For the SMM procedure, we select eight parameters that do not have well-established values in the literature. These are $\Omega = \left\{\psi, \omega^y, \sigma_\theta, \sigma_\lambda, \sigma_\zeta, \bar{\zeta}^\star,\ \Gamma,\ \zeta\right\}$, which are in order: (ψ) the firm exit rate, (ω^y) the share of inventories reincorporated as new-firm assets, (σ_θ) the standard deviation of technology shocks, (σ_λ) the standard deviation of foreign marginal utility shocks, (σ_ζ) the variance of foreign demand for home exports, (Γ) the share of home firms' assets retrievable upon default, (ζ) the share of the wage bill not retrievable if the household defaults, and finally $(\bar{\zeta}^\star)$ the long-run value of $\zeta_t^\star$.

The parameters are then chosen to target seven first moments in the data, shown in the first seven rows of Table 4. The first four rows in that table show the percentage changes in the period of sudden stop as compared to the long run average for four key macro-economic variables: (Q_t) the real exchange rate, (q_t) the price of capital, (GDP_t) calculated as $GDP_t = Y_t - C_t - I_t$, and (nx_t) are net exports scaled by GDP, calculated as $nx_t = (p_t^x x_t^I - y_t^I Q_t - y_t Q_t)/GDP_t$.

In the next three rows, the $duration_{ss}$ of a sudden stop is the average number of quarters that the constraint is binding in the simulated model. In the second row, '$f_t, \alpha = 1$' is the percent change in the ratio of trade credit to total imports when $\alpha = 1$, relative to its long run average. Recall in the model that $\alpha = 1$ is when all trade credit is home currency units. Finally, in the third row, $f_t, \alpha = 0$ is the change in trade credit over imports when all trade credit is in the foreign currency.

Reasonable bounds for the parameters are set according to what is often used for similar SOE

[12] The minimum reached by SMM is not necessarily a global one. We try to help our chances in finding a global, rather than a local solution by using a genetic solver instead of the more common Newton Solvers.

models, and following 'common sense.' From Gertler and Karadi (2011), the values of ψ are less than 1 but not too far from the consumers discount factor β. The value for ω^y is small and positive but never larger than 0.1. Variances in small open economy models for technology shocks, interest rate shocks and export demand rarely[13] exceed 0.05.

Table 3: **Baseline Model Parameters**

Parameter	Value	Description
η	4.61	Utility parameter for labor
ψ^L	0.5	Frische elasticity of labor supply
β	0.99	Consumer discount factor
γ	2	Coefficient of relative risk aversion
σ	0.8	Elasticity of substitution, final goods
$1-\alpha$	0.6	Labor share in production
ϕ	0.6	Share of home goods in consumption
ρ	0.7	Elasticity of substitution for final goods
ϱ	0.7	Share of capital in X_t
ξ^κ	0.25	Capital adjustment costs
$\bar{\zeta}^\star$	0.83	Long run mean of $\zeta^\star$ ($\star$)
ω^y	0.0012	New firm startup capital share ($\star$)
ψ	0.98	Firm exit rate ($\star$)
σ_ζ	0.067	Standard deviation of ϵ_ζ ($\star$)
σ_θ	0.022	Standard deviation of ϵ_θ ($\star$)
σ_λ	0.012	Standard deviation of ϵ_λ ($\star$)

The parameters are summarized in Table 3, with the ones calculated from SMM denoted with a $\star$ at the end of their description. Results from this calibrated model are then reported in Table 4. The *Model* values are calculated from a simulation of 15000 periods. Then for those periods with a binding household constraint, and for three period before and after, we average the log deviations of Q_t, Y_t, q_t, nx_t and f_t from the log of the simulated mean, and multiply by 100. The duration of the sudden stop is calculated as an average of the number of contiguous periods for which $\mu_t > 0$.

The model fits the data reasonably well. All of the standard macro-economic aggregates are moving in the correct direction, and most importantly, f_t behaves correctly for both $\alpha = 0$ and $\alpha = 1$. Magnitudes for the model are generally close to the data as well, with the exception of q_t, that is roughly 1/10 the value in the data. This is partly due to the fact that we did not include ξ^κ (the adjustment cost for capital producers) in the SMM procedure. As it stands, SMM with this global model is extremely time intensive, as the full model must be solved for each iteration

[13]In our own calibration of the unconstrained model to U.S. and Canadian data they hovered around 0.01. This calibration exercise of the unconstrained model is available upon request. It is omitted here because it is more lengthly than it is pertinent.

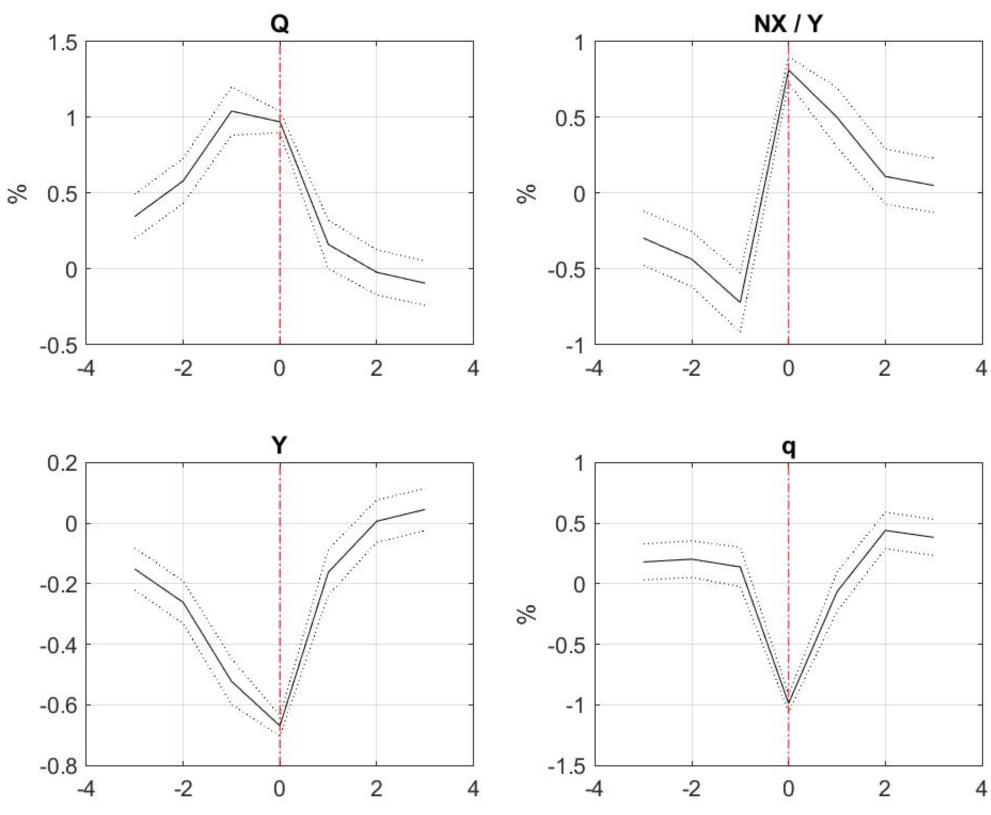
of the procedure. Including ξ^{κ} in the list of fitted parameters is, for now, not practical.

Figure 8a plots the number of periods while in a sudden stops for 10 values of α spanning from 0 to 1. This is a simple average for the percent of periods when $\mu_t > 0$. Moving from all trade to no trade in home currency results in an increase of 31% in this value, also presented as the last row in Table 4. From our data set on sudden stops, a rough measure of this change is the slope of a regression of the *Number of periods on average a country is in a sudden stop* onto the *Share of Trade in Home Currency.* The slope coefficient from this regression in Appendix D implies that there is an increase of somewhere between 18% in the data, lower than what the model implies, but similar in magnitude.

Table 4: **Calibrated Model Fit**

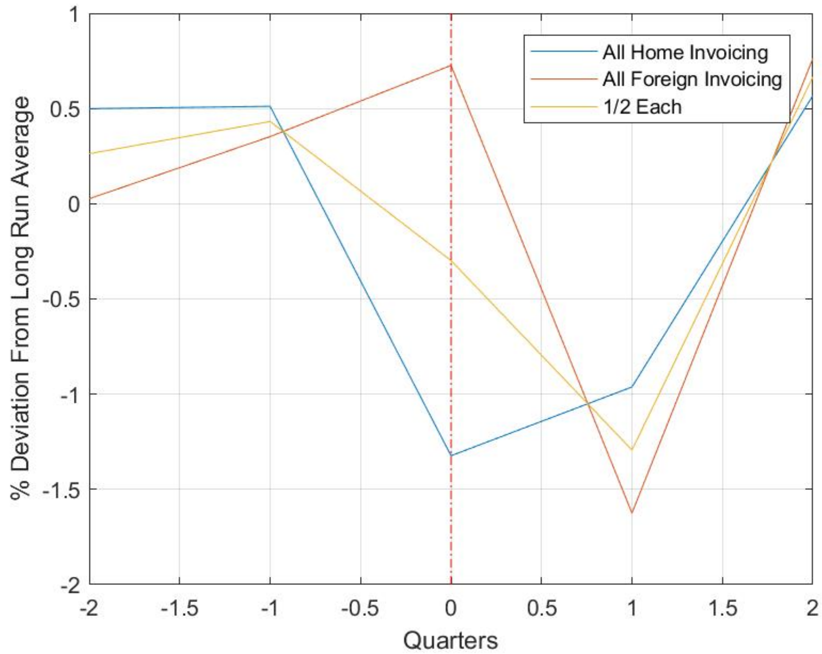
	Model	Data	
	Mean	Mean	Median
Q_t	0.98	1.56	0.80
q_t	-1.02	-11.59	-6.78
Y_t	-0.651	-1.86	-1.08
nx_t	0.78	1.47	1.25
$duration_{ss}$	1.9	2.5	2.2
$TC_t(\alpha = 1)$	0.71	1.82	-
$TC_t(\alpha = 0)$	-1.30	-1.675	-
π_{ss},α_0^1	31.91	$\in$ 8 to 14	-

Figure 6: Simulated Sudden Stop from the Model



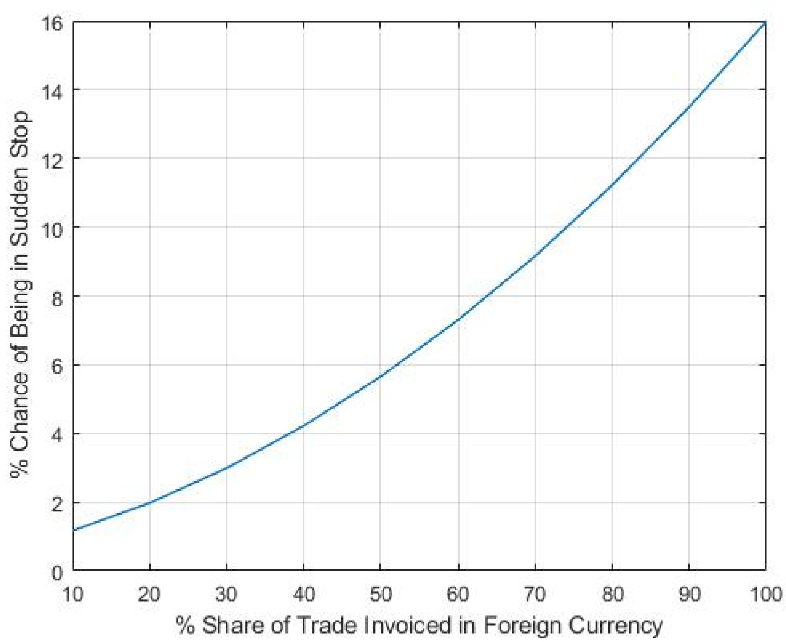
(a)

(a) Flow of Trade Credit and Sudden Stops



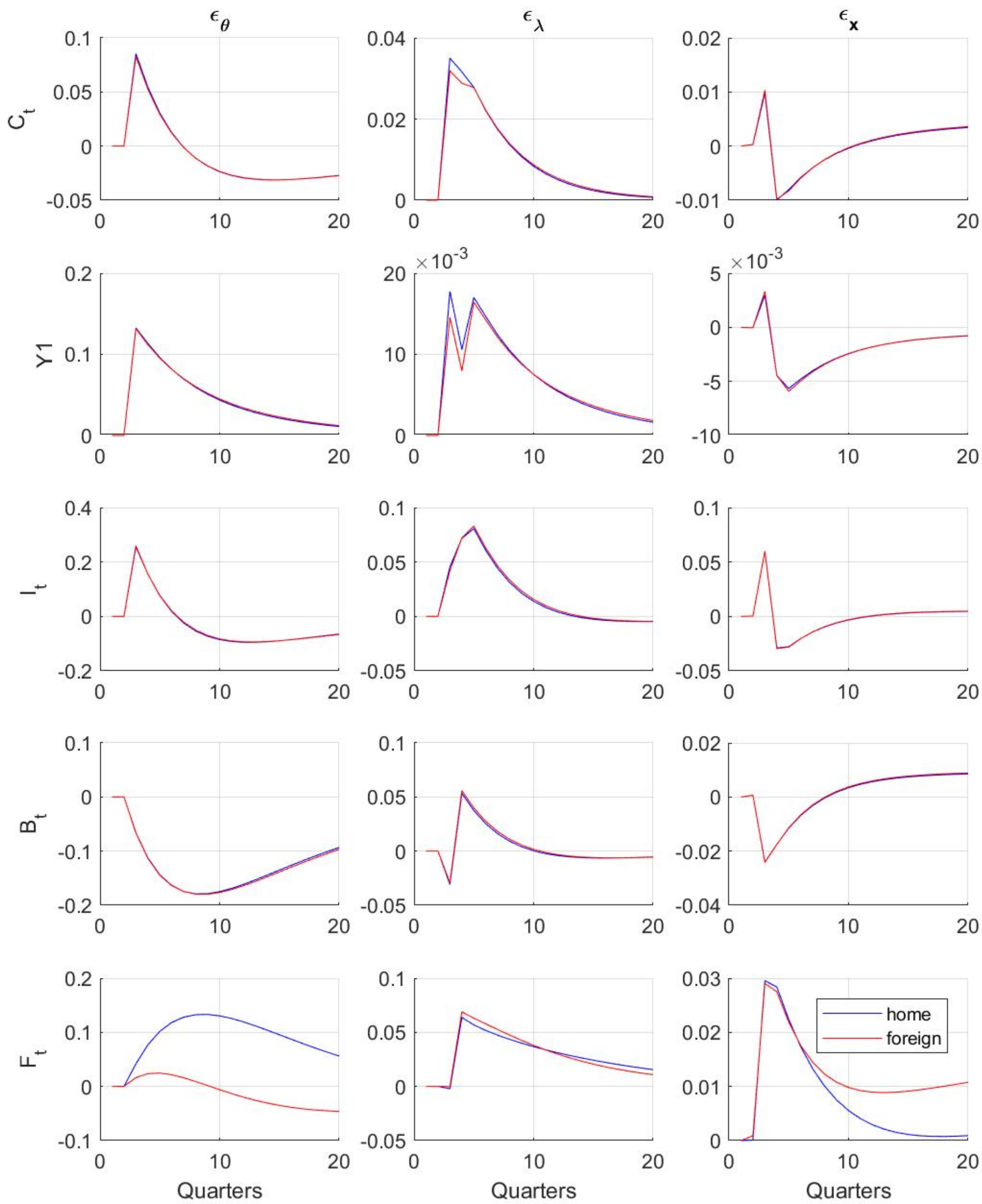
(b)

(a) Likelihood of Being in Sudden Stop



(b)

Figure 9: Impulse Responses



(a)

3 Intuition from the Model about the Role of Invoicing

In this section, we delve formally into the model to discuss the mechanisms that generate the results on trade credit behavior. So far, the results have been strictly numerical. The focus now will be in showing that the model can generate our *new* stylized fact: firms that invoice more in a foreign currency will tend to loose access to trade credit during a sudden stop. This result can be derived formally, conditional on the household's constraint binding (i.e. conditional on there being a sudden stop).

Here we will not focus so much on the behavior of other macro-aggregates, such as the real exchange, output, consumption, etc. Other excellent papers (Korinek and Mendoza (2014), Bianchi (2011)) make this a sole focus, and construct models that lend themselves to being solved by hand for formal results. In this paper, having shown numerically that the model can reproduce the behavior in those variables, this section will focus on new results around trade credit.

First, trading firms try to borrow more when the constraint on their value function (17) is binding. To remind the reader, f_t is trade credit scaled by imports, and χ_t is the Lagrange multiplier on the firms value function constraint. Below, this is written as a proposition, and then proven in the appendix.

Proposition 1
When the constraint in (17) is binding, an increase in χ_t will have a negative effect on trade credit flows, that is,

$$\frac{\partial f_t}{\partial \chi_t} < 0 \text{ when } \chi_t > 0$$

Proof. See Appendix A.
Intuitively this makes sense. When the firm is constrained, the return on imported goods is above the expected cost of trade credit financing ($v_t^I > 0$). The only way they can buy more imported goods is to borrow more, but this will tighten the constraint by lowering V_t. Using this result, it is straightforward to show that for some value of α, that we call $\bar{\alpha}_t$, trade credit will change from an outflow to an inflow during a sudden stop. As a reminder, μ_t is the Lagrange multiplier on the household constraint (6).

Proposition 2
Let $\tilde{Q}_t$ be the percent change in the real exchange rate over last period. When $\frac{\partial}{\partial \mu_t} E_t\left(\hat{\Omega}_{t+1}\tilde{Q}_{t+1}\right) <$

0, then[14]

$$\frac{\partial f_t}{\partial \mu_t} > 0 \quad \text{when} \quad \alpha < \bar{\alpha}_t$$
$$\frac{\partial f_t}{\partial \mu_t} < 0 \quad \text{when} \quad \alpha > \bar{\alpha}_t$$

for time varying cutoff value $\bar{\alpha}_t$ that is defined in the appendix.
Proof. See Appendix A.

An interesting side result from these two propositions is that the two constrains, the one on the firm and the one on the household, will move together. Formally, this amounts to

$$\frac{\partial \mu_t}{\partial \chi_t} > 0 \text{ when } \chi_t > 0 \text{ and } \mu_t > 0$$

and follows from the Implicit Function Theorem (again, shown in the Appendix). This certainly accords with the common understanding of sudden stops. It is not just a banking event, or a consumer event, but it also involves the firms balance sheets, as they become more constrained during crisis events.

4 Probit Regression for Sudden Stops

In this section, we run a simple set of regression that resemble Calvo et al. (2004), who provides intuition for sudden stops being a function of the absorption of tradeable goods and the degree of domestic liability dollarization. This regression equations is later taken up in Calvo and Talvi (2005b), where they study closely the case of Argentina and Chile and argues that this nicely exemplifies the scenario they laid out in their earlier paper. The regression model is,

$$\begin{aligned}\text{Sudden Stop}_{it} =& \beta_1 \left(\text{Liability Dollarization}_{it}\right) + \\ & \beta_2 \left(\frac{\text{Currenct Account Deficit}_{it}}{\text{Absorbtion of Tradables}_{it}}\right) + X_{it}\beta + e_{it}\end{aligned}$$

and the results for varying controls are presented in Table 5. We then amend this regression to include controls for the level of foreign invoicing, the net balance on trade credit, and the interaction of the two. The variable Foreign Invoicing$_{it}$ is calculated in a data consistent way.

[14]We ensure that this is true in the model simulations. This is simply saying that the real exchange rate is higher during a sudden stop than in the period following. Clearly this is true in the data, and it is an established characteristic of sudden stops.

First, suppose that

$$F_{it}\alpha_{it} = (X_{it}\alpha_{ix} - M_{it}\alpha_{im}) \star \text{Constant} \tag{30}$$

where F_{it} is the rate at which net trade credit accrues in the home currency, or rather, the rate at which the home country pays in advance for goods in its own currency. Shares α_{ix} and α_{im} are the reported shares of imports and exports denominated in home currency. The terms X_{it} and M_{it} are total exports and imports from country i. The term "Constant" is a real number that can be positive or negative (when positive, the countries leans towards open account payments, when negative, the countries lean towards Cash-in-Advance payments). The big assumption here is that the rate that exporters borrow or lend per unit sold is symmetric for the home and foreign countries. We can use the expression 30 together with its counterpart,

$$F_{it}(1 - \alpha_{it}) = (X_{it}(1 - \alpha_{ix}) - M_{it}(1 - \alpha_{im})) \star \text{Constant} \tag{31}$$

to obtain obtain a data consistent measure for α_{it}. By canceling out F_{it} and solving for α_{it}, we get,

$$\alpha_{it} = \frac{\alpha_{ix}X_{it} - \alpha_{im}M_{it}}{X_{it} - M_{it}} \tag{32}$$

Notice that this is now free of both the constant term and F_t. We focus on this measure in the data, and leave the data measures for F_t and the constant as controls. Because there is not a good data on the degree that countries pay early or late, there is no a-priori reason the signs on F_t in our probit regression should be positive or negative.

We then estimate the unconditional mean of Sudden Stop crisis in each country of this slightly smaller sample, and obtain confidence intervals by bootstrapping. This is shown in the first column of table 6. Then in the second column, we report the predicted likelihood of a sudden stop when Foreign Currency Invoicing is taken to zero for every country. Finally in the last column, we report the predicted likelihood of a sudden stop when foreign invoicing is taken to be complete.

4.1 The Model with Firm Hedging

A valid criticism of this model could be that in it, firms are extremely limited in their ability to hedge risk. By constraining the menu of assets to just one mixed currency investment, F_t, we have assumed something counter factual, and even gone so far as to assume the result. In the real world, exporting/importing firms can buy and sell assets, perhaps even to the extent that

Table 5: Probit Regression Results

	Dependent variable:					
	Probability of being in a Sudden Stop.					
	(1)	(2)	(3)	(4)	(5)	(6)
Liability Dollarization	7.328***	7.239***	6.454***	6.002***	9.236***	9.236***
	(−0.019)	(0.020)	(−0.488)	(−0.396)	(−1.879)	(−1.891)
CAD / Tradables	0.710***	0.708***	0.215***	0.009	0.888***	0.817***
	(0.003)	(0.002)	(−0.027)	(−0.030)	(−0.164)	(−0.200)
Foreign Invoicing		0.036***		0.020*		−0.002
		(−0.004)		(−0.012)		(−0.014)
Foreign Invoicing*Trade Credit				0.208***		0.188***
				(−0.003)		(−0.012)
Trade Credit				−0.137***		−0.145***
				(0.006)		(0.039)
Constant	−5.741***	−5.763***	−6.832***	−6.809***	−7.297***	−7.285***
	(−0.021)	(−0.170)	(0.212)	(0.188)	(0.379)	(1.126)
Controls	Y	Y	Y,L	Y,L	Y,L,E	Y,L,E
Observations	208	208	175	174	175	174
Log Likelihood	−74.878	−74.767	−64.918	−62.621	−57.565	−56.765
Akaike Inf. Crit.	219.757	221.533	193.836	195.242	185.130	189.530

Note: Y = Year dummies, E = Exchange Rate Regime, L = Level. Standard errors are white robust.Countries: Thailand, Republic of Korea, Norway, Finland, United Kingdom, Greece, Hungary, Italy, Netherlands, Sweden, Japan, Brazil, Australia, Czech Republic, Estonia, Lithuania, Poland, Slovakia, Slovenia, Canada, Cyprus, Luxembourg, France, Denmark, Ireland, Austria, Belgium, Germany, Portugal.

they have achieved perfect risk sharing.

In this section, we explore this critique and allow firms to trade an *additional* 'bond', or trade credit asset, with the foreign firm. The idea here is to allow the firm to have access to a second asset that will allow them to always create a portfolio with their optimal mix of home and foreign trade credit assets. Hedging assets, however, will have an adjustment cost associated with them that is scaled by the factor ξ. In the real world, when there is money and nominal risk, this hedging asset would take the form of a forward contract or some combination of nominal bonds. In this model, as there is no money but only real risk, the firm can accomplish the same task by purchasing the a combination of additional firm loans from abroad, in units of the home and foreign good, respectively G_t^h and G_t^f. The firm now can allocate their net assets across imports, normal trade credit F_t, and then additional trade credits G_t that comes with quadratic adjustment costs scaled by ξ.

$$N_t = y_t^I Q_t + F_t + G_t^h + G_t^f Q_t - \frac{\xi}{2}\left(G_t^h\right)^2 - \frac{\xi}{2}\left(G_t^f\right)^2 Q_t \tag{33}$$

Now the firm solves a similar problem to the baseline model, except there are new state variables to help the firm hedge. Result 2 summarizes the new solution.

Table 6: Probability of Being in a Sudden Stop

Country	Fitted Probability of Sudden Stop	Foreign Invoicing to Zero	Foreign Invoicing to One
Norway	41.3	36.8	74.5
	(58.5,26.1)	(59,27.2)	(59.4,28.1)
Brazil	37.4	32.6	72.5
	(61.8,24.9)	(59.4,26)	(62.2,26.3)
Canada	34.8	30.2	76
	(49.3,14)	(49.7,14.6)	(49.5,13.1)
Republic of Korea	30.9	27.6	59.3
	(43.5,18.5)	(42.6,18.3)	(42.9,18.4)
Sweden	26.8	24	64.4
	(35.4,13.3)	(35.2,12.4)	(35.6,12.7)
Thailand	24.7	23.2	36.3
	(48.1,11.9)	(48.4,11.9)	(47.2,11)
Greece	22	19.5	46.8
	(61,0.5)	(59.8,0)	(62.9,0.3)
Australia	17	14.4	55.7
	(33.4,5.7)	(34.3,6.9)	(33.7,6.6)
Hungary	16.2	14.3	29.6
	(30.6,0)	(28.9,0)	(31.4,0)
United Kingdom	18.3	13.9	46.9
	(27.7,4.5)	(28.6,4)	(28.5,4.8)
Italy	15.4	12.7	52.1
	(27.3,6.3)	(27.8,6.1)	(27.3,6.8)
Cyprus	14	11.5	51.9
	(20.3,1.3)	(21.8,1.5)	(21.6,1.3)
France	14.4	11.4	51.5
	(26,4.4)	(26.8,5)	(24.5,4.5)
Germany	13.6	11.1	47.6
	(27.2,0)	(27.2,0)	(26.6,0)
Finland	14.2	10.8	45.8
	(27.3,2.2)	(25.4,3)	(25.9,2.4)
Denmark	12.9	10.4	55.5
	(26,0)	(26.4,0)	(25.7,0)
Luxembourg	11.3	9.4	50.7
	(32,0)	(30.9,0)	(31.2,0)
Ireland	11.4	9	45.8
	(25.1,2.4)	(23.4,2.7)	(23.5,2.5)
Portugal	9.5	8.5	40.7
	(21.9,0)	(22.1,0)	(23.3,0)
Austria	9.4	8.2	42.3
	(19,0)	(18.2,0)	(18.9,0)

Result 2 Similar to baseline model, the value function is a sum of time varying coefficients v_t^I, v_t^n, $v_t^{g,h}$, $v_t^{g,f}$, $v_t^{\xi,h}$, $v_t^{\xi,f}$ on the state variables $y_t^I Q_t$, N_t, G_t^h, G_t^f.

$$V_t = v_t^I y_t^I Q_t + v_t^n N_t + v_t^{g,h} G_t^h + v_t^{g,f} Q_t G_t^f - v_t^{\xi,h} \frac{\xi}{2} \left(G_t^h\right)^2 - v_t^{\xi,f} \frac{\xi}{2} Q_t \left(G_t^f\right)^2 \tag{34}$$

with

$$v_t^{g,h} = E_t \left(\hat{\Omega}_{t+1} \left[\bar{R}^c - R_{t+1}^c \right] \right) \tag{35}$$

$$v_t^{g,f} = E_t \left(\hat{\Omega}_{t+1} \left[\bar{R}^c \frac{Q_{t+1}}{Q_t} - R_{t+1}^c \right] \right) \tag{36}$$

$$v_t^{\xi,h} = v_t^{\xi,f} \tag{37}$$

$$v_t^{\xi,f} = v_t^n \tag{38}$$

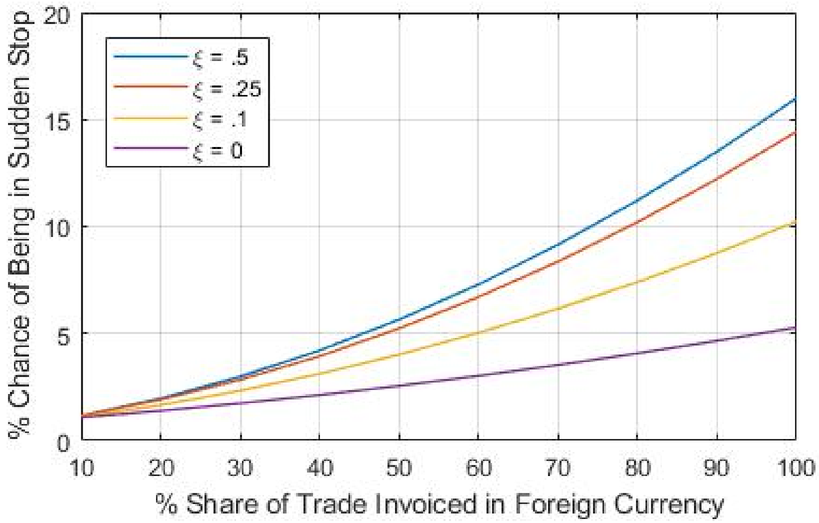
and holdings of the G_t^h and G_t^f will be

$$\xi G_t^h = \frac{v_t^{g,h}}{-v_t^n} \quad \text{and} \quad \xi G_t^f = \frac{v_t^{g,f}}{-v_t^n}.$$

The variables v_t^I, v_t^n, $\hat{\Omega}_{t+1}$ and χ_t are unchanged from the baseline model.
Proof. See Appendix A.

We run this model using the identical calibration to the baseline model (see Table 3), and only vary the adjustment cost ξ of purchasing new assets G_t^h and G_t^f. Taking the value of ξ from 0.5 to 0, makes it so that the imposed mix in F_t, given by share α, has no effect on the length of time spent in a sudden stop.

Figure 10: Time in Sudden Stop with Hedging



(a)

5 Conclusion

In this paper we identify a large sample of sudden stops in the data and uncover a new stylized fact about the behavior of trade credit during these events. In particular, firms that invoice their imports in a foreign currency will tend to loose access to trade credit during a sudden stop. To provide intuition for this result, this paper then builds on a canonical framework of sudden stops following Mendoza (2010). The key ingredient to replicating the observed behavior is a trading firm that is subject to a separate constraint, imposed by their foreign counterpart, on the firms value function as in Gertler and Karadi (2011). In the context of a sudden stop, when output falls and real exchange rates depreciate, this added constraint will bind more tightly for firms that invoice in a foreign currency. On average, firms with tighter constraints import less, earn less income, and will exhibit higher volatility of import demand. This volatility is passed onto the household, so that in the end, the frequency of sudden stops is higher for an SOE that invoices more in a foreign currency.

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A Appendix

A.1 Proofs

Proof of Result 1

The firm will solve their problem in (18) subject to their definition for net assets in Equation 16 and the constraint on imports (17). Starting with a conjecture that the value function is linear and equal to $V_t = v_t^I Q_t y_t^I + v_t^n N_t$, along with the definition for net assets, $N_t = y_t Q_t + F_t$, we set up the Lagrangian function,

$$\max_{y_t^I, F_t} \mathcal{L} = v_t^I Q_t y_t^I + v_t^n \left(y_t^I Q_t + F_t \right) + \mu_t \left[v_t^I Q_t y_t^I + v_t^n \left(y_t^I Q_t + F_t \right) - \Gamma y_t^I Q_t \right] \tag{39}$$

From the first order conditions we have the value of the multiplier.

$$\chi_t = \frac{v_t^I}{\Gamma - v_t^I} \tag{40}$$

From the constraint and the definition of net assets, we can arrive at

$$\frac{N_t \Gamma v_t^n}{\Gamma - v_t^I} = V_t \tag{41}$$

First we substitute this for the value function in the firms end-of-period optimization problem. Then using (15), we substitute N_{t+1} in the firms end-of-period optimization problem.

$$V_t = \max_{F_t^f, y_t^I} E_t N_{t+1} \Omega_{t+1} \left\{ (1-\psi) + \psi \frac{\Gamma v_{t+1}^n}{\Gamma - v_{t+1}^I} \right\} \tag{42}$$

$$= \max_{F_t^f, y_t^I} E_t N_{t+1} \hat{\Omega}_{t+1} \tag{43}$$

$$= \max_{F_t^f, y_t^I} E_t \left(y_t^I Q_t \left(\frac{r_{t+1}^I}{Q_t} - R_{t+1}^c \right) + N_t R_{t+1}^c \right) \hat{\Omega}_{t+1} \tag{44}$$

$$= y_t^I Q_t E_t \left(\hat{\Omega}_{t+1} \left[\frac{r_{t+1}^I}{Q_t} - R_{t+1}^c \right] \right) + N_t E_t \left(\hat{\Omega}_{t+1} R_{t+1}^c \right) \tag{45}$$

$$= v_t^I Q_t y_t^I + v_t^n N_t \tag{46}$$

Moving from (42) to (43) defines $\hat{\Omega}_{t+1}$, and moving from (44) to (45) defines v_t^I and v_t^n ■

Proof of Result 2 The setup of the problem is identical to Result 1, with two changes. First, net assets evolve according to (47) below and (33) in the paper, instead of (11) and (15) as before. Also we need to conjecture a different value function to solve the model.

$$N_t = y_{t-1}^I Q_{t-1}\left(\frac{r_t^I}{Q_{t-1}} - R_t^c\right) + N_{t-1}R_t^c + \bar{R}^c G_t^h + \bar{R}^c G_t^f \frac{Q_t}{Q_{t-1}} + \frac{\xi}{2}(G_t^h)^2 + \frac{\xi}{2}(G_t^f)^2 Q_t \tag{47}$$

As before, we substitute this for the value function in the firms end-of-period optimization problem. Then using (47), we substitute N_{t+1} in the firms end-of-period optimization problem and we follow the same steps as in (42) to (45). Making the same substitutions as before, we find that

$$v_t^{\xi,h} = v_t^{\xi,f} = v_t^n \tag{48}$$

$$\tag{49}$$

Then the Lagrangian is,

$$\max_{F_t^f, y_t^I, G_t^h, G_t^f} \mathcal{L} = V_t + \mu_t\left[V_t - \Gamma y_t^I Q_t\right] \tag{50}$$

Where V_t is the value function in (34). There are two new first conditions for the extra state variables G_t^h and G_t^f.

$$v_t^{g,h} + v_t^{\xi,h} G_t^h = 0$$
$$v_t^{g,f} + v_t^{\xi,f} G_t^f = 0$$

Re-arranging these will give us the firms' holdings of these two assets reported in the paper. ■

Proof of Proposition 1.

From above, we showed that the ratio of trade credit to imports is $f_t = \frac{\Gamma - v_t^I}{v_t^n} - 1$. The derivative of this expression with respect to the firms constraint is

$$\frac{\partial f}{\partial \chi_t} = \left(\frac{v_t^I - \Gamma}{(v_t^n)^2}\right)\frac{\partial v_t^n}{\partial \chi_t} - \frac{1}{v_t^n}\frac{\partial v_t^I}{\partial \chi_t} \tag{51}$$

Then using the definition for the constraint, i.e. $\chi_t = \frac{v_t^I}{\Gamma - v_t^I}$, we have that

$$\frac{\partial v_t^I}{\partial \chi_t} = \frac{\Gamma}{(1+\chi_t)^2} \tag{52}$$

Now using the definition for net assets from above, we will can re-arrange the constraint to get

v_t^n on the left,

$$v_t^n = \frac{y_t^I Q_t}{N_t}\left(\Gamma - v_t^I\right)$$

Now we need to substitute out the fraction with net assets and imports. Using the definition of net assets we have,

$$\begin{aligned} N_t &= F_t + y_t^I Q_t && \text{dividing by } y_t Q_t \\ \frac{N_t}{y_t Q_t} &= \frac{F_t}{y_t^I Q_t} + 1 = f_t + 1 && \text{using the definition of } f_t \end{aligned}$$

Then we can write v_t^n in terms of v_t^I and f_t. This gives us

$$v_t^n = \frac{\Gamma - v_t^I}{f_t + 1}$$

differentiating this expression with respect to χ_t yields,

$$\frac{\partial v_t^n}{\partial \chi_t} = \left(\frac{v_t^I - \Gamma}{\left(1+f_t\right)^2}\right)\frac{\partial f_t}{\partial \chi_t} - \frac{\partial v_t^I}{\partial \chi_t}\left(\frac{1}{1+f_t}\right) \tag{53}$$

Now we substitute expression (52) and (53) into (51),

$$\begin{aligned} \frac{\partial f}{\partial \chi_t} &= \left(\frac{v_t^I - \Gamma}{(v_t^n)^2}\right)\left(\frac{v_t^I - \Gamma}{\left(1+f_t\right)^2}\frac{\partial f_t}{\partial \chi_t} - \left(\frac{\Gamma}{\left(1+f_t\right)\left(1+\chi_t\right)^2}\right)\right) - \frac{1}{v_t^n}\left(\frac{\Gamma}{\left(1+\chi_t\right)^2}\right) \\ &= \Gamma \frac{f_t + 1}{\left(1+\chi_t\right)^2 v_t^n}\left(\frac{f_t + 1 - 1/\phi_t}{1/\phi_t^2 - \left(1+f_t\right)^2}\right) \\ &= -\Gamma \frac{f_t + 1}{\left(1+\chi_t\right)^2 v_t^n}\left(\frac{1}{f_t + 1 + 1/\phi_t}\right) < 0 \end{aligned}$$

where $\phi_t = \frac{v_t^n \Gamma}{\Gamma - v_t^I}$, and we make the third step in the algebra by factoring the rightmost parenthesis and canceling. Since it must be that $\Gamma - v_t^I \geq 0$ when the firm is constrained, then $\phi_t > 0$ when $\chi_t > 0$. Also, $f_t + 1 \geq 0$ as long as the constraint binds. Therefore it must be that $\partial f_t / \partial \chi_t < 0$ ■.

Proof of Proposition 2.

Starting with the definition for the constraint

$$\chi_t = \frac{v_t^I}{\Gamma - v_t^I}$$

we then differentiate with respect to μ_t to arrive at,

$$\frac{\partial \chi_t}{\partial \mu_t} = \frac{\partial v_t^I}{\partial \mu_t}\left(\frac{\Gamma}{\left(\Gamma - v_t^I\right)^2}\right) \tag{54}$$

From the Implicit Function Theorem, it must be that

$$\frac{\partial f_t}{\partial \mu_t} / \frac{\partial f_t}{\partial \chi_t} = -\frac{\partial \chi_t}{\partial \mu_t} \tag{55}$$

Therefore, using (54) in(55), we see that the derivative of trade credit with respect to the sudden stop Lagrange multiplier will follow the sign of $\partial v_t^I / \partial \mu_t$ since, from Proposition 1, we know that $\partial f_t / \partial \chi_t$ is always negative.

$$\frac{\partial f_t}{\partial \mu_t} = -\frac{\partial f_t}{\partial \chi_t} \frac{\partial v_t^I}{\partial \mu_t} \frac{\Gamma}{(\Gamma - v_t^I)^2} \tag{56}$$

The last term on the right is clearly always positive, since Γ is a parameter chosen to be greater than zero. What remains is to characterize the term $\partial v_t^I / \partial \mu_t$. This will be,

$$\frac{\partial v_t^I}{\partial \mu_t} = -\frac{\partial}{\partial \mu_t} E_t \left(\hat{\Omega}_{t+1} \right) - (1 - \alpha) \frac{\partial}{\partial \mu_t} E_t \left(\hat{\Omega}_{t+1} \tilde{Q}_{t+1} \right) + \frac{\partial}{\partial \mu_t} \left(\hat{\Omega}_{t+1} r_{t+1}^I \right)$$

where $\tilde{Q}_t = Q_t / Q_{t-1} - 1$ is the change over the prior period. We now have to use our assumptions about a sudden stop event. When $E_t \left(\hat{\Omega}_{t+1} \tilde{Q}_{t+1} \right) < 0$,

$$\alpha < 1 - \frac{\frac{\partial}{\partial \mu_t} E_t \left(\hat{\Omega}_{t+1} \left[\frac{r_{t+1}^I}{Q_t \bar{R}^c} - 1 \right] \right)}{\frac{\partial}{\partial \mu_t} E_t \left(\hat{\Omega}_{t+1} \tilde{Q}_{t+1} \right)} = \bar{\alpha}_t \tag{57}$$

Therefore, these statements are equivalent

$$\alpha < \bar{\alpha}_t \leftrightarrow \frac{\partial v_t^I}{\partial \mu_t} > 0 \leftrightarrow \frac{\partial f_t}{\partial \mu_t} > 0$$

We can summarize this result. When $E_t \left(\hat{\Omega}_{t+1} \tilde{Q}_{t+1} \right) < 0$, which is what we observe in the data for sudden stops in general (see Figure 1), then

$$\frac{\partial f_t}{\partial \mu_t} > 0 \quad \text{when} \quad \alpha < \bar{\alpha}_t$$
$$\frac{\partial f_t}{\partial \mu_t} < 0 \quad \text{when} \quad \alpha > \bar{\alpha}_t$$

which was the original proposition ■.

B Description of Data

Table 7: Data Sources

Currency Data		
Country/Topic	Year / Source	Description
Thailand	1993-2016, Bank of Thailand	Annual Data on exports and imports of total international trade invoiced in Thai Baht and other major currencies. Portion of home currency trade extrapolated to monthly data and to include 2017-2018 and 1980-1993.
Taiwan	2008-2017, Bank of Taiwan and GIR	Annual Data on exports and imports of total international trade invoiced in foreign currency.
Japan	1980, 1988, 1990 - 2015, Ministry of Finance of Japan and The Research Institute of Economy Trade and Industry[15] and GIR	Annual data supplied for all international trade for exports and imports. Values are extrapolated using linear splines between 1980, 1988 and 1990 and extended to 2018 again using linear splines.
Australia	2011-2015, Australia Bureau of Statistics and GIR [16]	Data is annual for all trade, separated by imports and exports.
Belgium, France, Portugal, Poland, Bulgaria, Cyprus, Czecheslovakia, Spain, Estonia, Greece, Italy, Lithuania, Luxembourg, Latvia, Malta Romania, Slovenia, Sweden	2000 - 2015. ECB, GIR and Kamps (2006)	A note on the ECB Currency Data. Data is annual for trade in goods. Because data is only reported as a share of extra-euro-area trade, we must scale the reported share by the share of trade to the euro area. We then assume that all within-euro area trade, (following ascension to the Euro), is denominated in the countries home currency of the Euro.
United States	Kamps (2006), GIR and Goldberg and Tille (2006)	2004, 2016.

[15]More about REITI can be found here: https:/www.rieti.go.jp/en/database/index.html

[16]See Table 6 and 7 in Report 5368, http://www.abs.gov.au/

Continuation of Data Sources		
Country/Topic	Year/ Source	Description
Canada	Devereux, Tomlin, and Dong (2015)	Average of 2002-2008 Data
Macroeconomic Variables		
Real GDP	IFS	Quarterly and Annual. We use IFS series on both levels of Real GDP, and in percent changes over the same period in the previous year.
Nominal GDP	IFS	Quarterly, measured in the domestic currency
Population	IFS	Annual data, total number of persons.
Nominal Exchange Rates	IFS, ECB	Annually, Quarterly Monthly, period averages of the domestic currency relative to the U.S. dollar end Euro.
Real Exchange Rates	IFS	Annually and Quarterly, Real Effective Exchange Rate based on Consumer Price Index.
Exchange Rate Arrangements	Ilzetzki et al. (2017)	We use the coarse classification where classifications codes are categorized into six categories (1 to 6, with 1 being fixed exchange rate policy)[17]
U.S. Interest Rate	FRED	Three month U.S. treasury bond in the secondary market
International Reserves	IFS	Monthly national holdings of international reserves, converted to U.S. Dollars.
Measurements of Property Rights	Doing Business Survey (World Bank)	Available Annually, we principally use the Insolvency Recovery of Assets measurement as a measure of property rights.
Crude Oil Price	FRED	Monthly Global price of Brent Crude in U.S. Dollars per Barrel.[18]
Net Foreign Assets	Lane et al (2015) Bénétrix et al. (2015)	The data is annual time series, and net foreign assets are calculated as the share of the GDP, 1990 - 2012 for most countries.
Monthly Trade in Goods	DOT (IMF)	Monthly data in U.S. nominal dollars.
Foreign Currency Deposits	Bank of International Settlements	The BIS Locational Survey.
Inflation	FRED	Consumer price index

[17] See Carmen Reinhart's Website for details at http://www.carmenreinhart.com/data/browse-by-topic/topics/11/

[18] https://fred.stlouisfed.org/

Continuation of Data Sources		
Country/Topic	Year/ Source	Description
Trade Credits and Advances	IFS, ECB	Net changes in assets and liabilities owed to/by foreigners. Reported regularly in national Balance of Payments at a quarterly interval. For those quarter missing in the IFS database, we use to the ECB Data Warehouse and national websites to fill the gaps.
Capital Flows	IFS and national bank websites	Flows in Portfolio investment, Direct Investments and Other Investment (including Trade Credits).
Letters of Credit, value	SWIFT	2010 - 2015 for all countries in the sample. To construct the file used in the analysis we have to take several steps to clean the data. Following Niepmann and Schmidt-Eisenlohr (2017a), we exclude transactions to and from the following countries, as these countries are often used as tax havens and the LOC traffic with them misrepresents LOC usage for trade reasons. These countries are: Netherlands Antilles, United Arab Emirates, Bahrain, Bahamas, Belize, Bermuda, Barbados, Cayman Islands, Cyprus, Grenada, Hong Kong, Oman, Ireland, Jordan, Lebanon, Macao, Monaco, Maldives, Malta, Mauritius, Seychelles, Taiwan, Vanuatu, Samoa.
Stock Index	IFS	Financial Market Prices, Equities, Index, annual.

The acronyms in this table are the following. GIR: Gopinath, Itskhoki, and Rigobon (2010), ECB: European Central Bank, DOT: Directions of Trade Statistics, IFS: International Financial Statistics, FRED: Federal Reserve Economic Data, SWIFT: Society for Worldwide Interbank Financial Telecommunication.

B.1 Appendix: Sudden Stops

Table 8: Sudden Stops and Flights

	Net Stops		Gross Stops		Sudden Flight	
Country	Start	End	Start	End	Start	End
Australia	2000m1	2001m03	1997q3	1998q1	1995q4	1996q3
	2007m1	2008m09	2005q1	2005q4	2004q1	2004q3
	2010m08	2011m05	2012q2	2012q3	2006q2	2007q1
			2016q2	2016q4		
Belgium	2009m12	2010m12	2008q4	2009q3		
Brazil	1993m03	1993m11	1995q1	1995q2	1994q2	1994q4
	1997m03	1997m06	1999q1	1999q2	1998q4	1999q2

	2004m07	2005m02	2008q2	2009q3	2006q4	2007q3
	2008m07	2009m09				
	2012m03	2013m01				
	2015m08	2016m08				
Canada	1994m11	1996m09				
	1999m11	2001m09				
Cyprus	2007m04	2007m05	2009q4	2011q2	2007q4	2008q1
					2012q1	2012q4
Czech Republic	1997m01	1997m03	2003q2	2004q1	2003q3	2005q1
	2012m03	2012m08	2006q2	2006q4	2007q3	2008q3
	2014m11	2015m07	2008q4	2009q3		
Germany	1993m09	1994m01	1994q1	1994q4	1993q1	1993q4
	2001m12	2003m04	2001q1	2002q2	2005q1	2005q4
	2007m04	2008m07	2008q3	2009q3		
Denmark	1991m05	1992m02	1994q3	1995q1	1993q3	1994q2
	1994m02	1994m03	2001q2	2002q1	1999q4	2001q1
	1998m1	1999m02	2008q4	2009q4	2005q2	2005q4
	2000m03	2001m01				
	2004m05	2004m07				
	2005m1	2006m06				
	2008m08	2008m11				
	2010m05	2011m03				
	2016m01	2016m07				
Spain	1992m09	1993m1	2008q1	2009q4	2014q2	2015q1
	2009m02	2010m04				
	2012m11	2014m01				
Estonia	1998m12	2000m04	1998q4	1999q3	2003q3	2005q3
			2008q2	2009q3	2007q2	2008q1
			2015q1	2015q4		
Finland	1991m05	1992m04	2001q1	2002q1	1993q1	1993q3
	1993m09	1993m11	2009q2	2009q3	1998q4	1999q1
	1995m06	1996m08	2012q3	2013q3	2000q1	2000q4
					2010q2	2011q1
France	1991m1	1992m1	2002q1	2002q3	1997q4	1998q3
	2012m03	2012m1	2008q1	2009q3	2001q1	2001q2
					2005q3	2006q1
United Kingdom	2008m1	2009m07	2001q3	2002q3	1992q4	1993q2
			2008q2	2009q2	2000q3	2000q4
Greece	1992m09	1992m12	1995q4	1996q2	2012q1	2012q4
	1995m1	1996m08	1997q3	1999q2		
	1997m09	1999m06	2006q1	2006q4		
	2000m07	2001m07	2010q2	2011q2		
	2009m04	2010m04				
Hungary	1994m12	1995m02	1996q4	1997q1	2001q2	2002q3
	1996m05	1996m1	2002q2	2002q3	2003q4	2004q2
	2010m03	2011m02	2009q1	2010q2	2006q1	2008q1

	2012m03	2012m12				
	2015m03	2015m09				
Ireland	2009m03	2010m06	2016q4	2017q1		
	2015m03	2016m07				
Italy	1991m03	1992m04	1992q4	1993q3	2003q1	2003q4
	1998m12	1999m06	2000q4	2002q3	2005q1	2005q4
	2012m02	2014m02	2007q4	2008q4		
Japan	2004m12	2005m12	2008q3	2009q3	2004q4	2005q1
					2010q2	2011q1
South Korea	1997m09	1998m11	1997q2	1998q4	1994q4	1995q4
	2001m03	2001m1	2008q2	2009q3	2002q4	2004q3
	2005m11	2006m04			2006q1	2007q4
	2008m04	2009m07			2016q4	2017q2
	2010m11	2011m04				
	2015m05	2016m02				
Lithuania	1999m07	2000m06	2000q4	2001q3	2004q1	2004q4
	2008m08	2009m09	2008q3	2009q4	2015q1	2015q4
	2013m02	2013m04				
	2015m01	2015m12				
Luxembourg	2006m05	2008m08	2008q4	2009q2	2015q3	2015q4
	2014m05	2014m11	2014q2	2014q4		
			2016q1	2016q4		
Malta	2005m01	2005m05	2008q3	2009q4	2002q2	2002q3
	2007m05	2007m1			2004q1	2006q2
					2007q3	2007q4
Netherlands	1994m02	1994m05	2002q1	2002q4	1997q4	1998q4
	2003m05	2005m08	2008q1	2009q3	2003q4	2005q3
	2016m06	2017m04				
Norway	1991m05	1991m12	2001q3	2002q1	1995q2	1996q2
	1997m1	1998m02	2007q4	2009q4	2000q2	2001q2
	2000m03	2001m09			2005q4	2006q4
	2008m02	2009m03			2010q4	2011q1
Poland	2008m11	2009m09				
	2012m02	2012m08				
Portugal	1992m11	1993m1	2010q4	2011q3	2009q4	2010q2
	2011m07	2013m02				
Slovakia	1999m04	1999m09	2012q2	2012q4	2013q2	2013q4
	2003m08	2004m06				
	2006m02	2006m04				
	2008m09	2009m12				
Slovenia	1996m03	1996m07	2008q3	2009q3	2002q4	2003q3
	1998m06	1999m02			2005q3	2006q2
	2003m11	2004m1			2014q3	2014q4
	2007m01	2007m12				
Sweden	1991m1	1992m08	1997q1	1997q3	1995q3	1996q3
	1993m09	1994m01	2008q4	2009q3	2006q4	2007q4

	1995m1	1996m09	2014q4	2015q2		
	2010m1	2011m09				
Thailand	1992m02	1993m02	1996q3	1998q2	1995q3	1996q1
	1996m11	1998m07	2007q1	2007q3	2005q1	2006q1
	2009m02	2009m07	2011q4	2012q3	2009q4	2010q1
	2011m09	2012m08				
	2013m09	2014m07				
Taiwan	1995m12	1996m08	1997q4	1998q3	1996q1	1996q3
	2011m09	2012m08	2001q1	2001q2	2000q1	2000q4
			2005q1	2005q2	2003q3	2004q1
			2008q4	2009q2		
United States	1990m09	1992m05	1998q1	1999q1	1995q3	1996q1
	2009m01	2010m05	2001q3	2002q2	1997q1	1997q3
			2008q1	2009q2	2004q1	2004q4
					2006q4	2007q3

Source: Various data sources described in Table 7 and Authors calculations.

B.2 Robustness

As added regressors in X_{it}, we now include $INSOL_i$ is the per-country average share of Recovery on Insolvent Assets, taken as an average of yearly observations. The data are from the World Bank's *Doing Business Survey*. Second, HL_i is data from the Bank of International Settlements on the share of all local positions (within the reporting country) in home currency as a share of all instruments in all currencies.

$HMLOC_{it}$ and $HXLOC_{it}$ are shares of LOC trade in home currency over total trade. Finally WL_i is the share of just foreign liabilities in home currency as share of total liabilities. This measure is included to address the concern in Calvo et al (2004) for Domestic Liability Dollarization, a feature of developing countries that has been shown to deepen the recession during and after a sudden stop. As with HL_i, WL_i is calculated from the BIS Locational Statistics Database as an average over the period of available data on this measure, which for most countries in the data set, starts around 2012 and ends in the first quarter of 2018.

The variable $HMLOC_t$ are the home currency imports using letters of credits as a share of total imports, and $HXLOC_t$ is the same but for exports.

Figure 11: An Example of Sudden Stops in Thailand

(a) Net Capital Flows

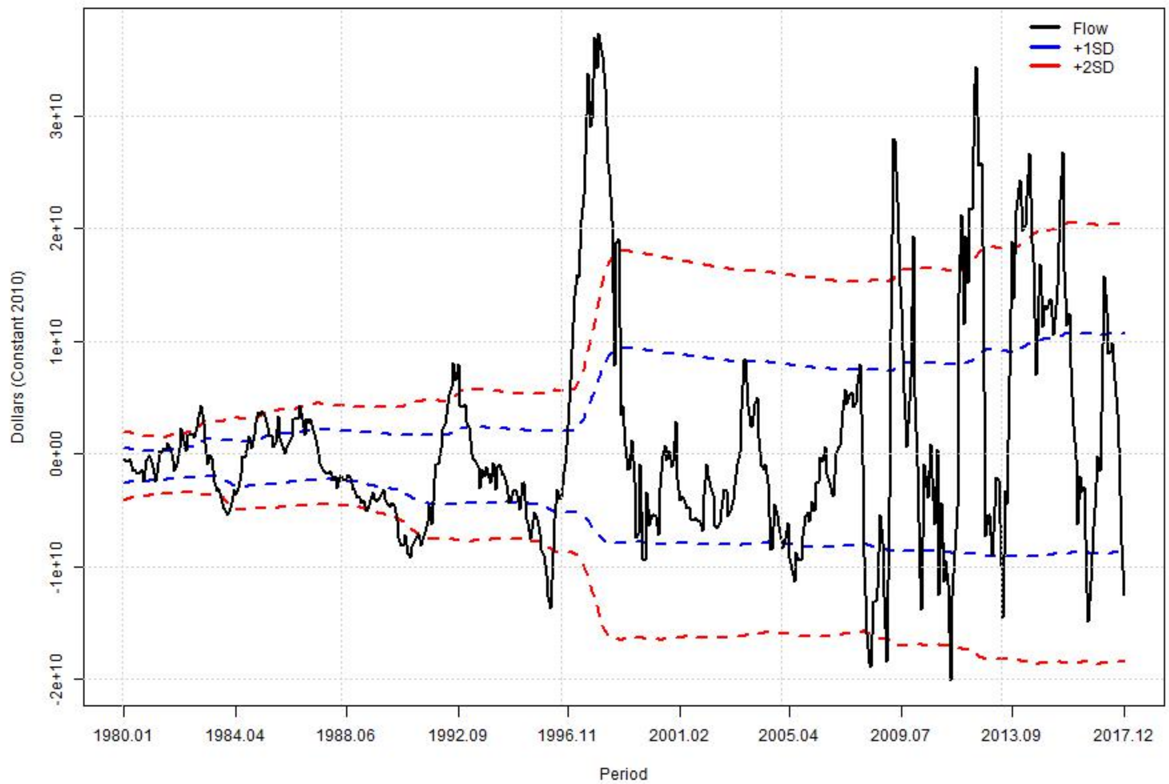


Table 9: Regression 2 Results

	Dependent variable:					
	100∗Net Flow of Trade Credit / Imports					
		Gross S.S.			Flight	
	(1)	(2)	(3)	(4)	(5)	(6)
$SuddenStop(t = 0)$	0.106	0.389	0.625	1.026	0.381	2.931
	(−0.488)	(−0.349)	(−0.480)	(−0.902)	(−0.880)	(−2.220)
$SuddenStop(t = 0) * HM_{it}$			−0.390			-6.527^{**}
			(0.330)			(2.852)
ERA_t		13.228^{***}	12.709^{***}		13.939^{***}	13.917^{***}
		(−0.754)	(−0.733)		(−1.526)	(−1.359)
NFA_{t-1}		−0.640	-0.800^{*}		-0.976^{**}	-0.997^{**}
		(0.436)	(0.412)		(0.435)	(0.450)
Observations	1,871	1,215	1,215	1,814	1,161	1,161
R^2	0.147	0.211	0.218	0.137	0.214	0.222
Adjusted R^2	0.070	0.109	0.111	0.059	0.112	0.114

Note: *p<0.1; **p<0.05; ***p<0.01. All regressions include country fixed effects and time period dummies (quarterly).

Table 10: Regression 3 Results

	Dependent variable:					
			Trade Credit/Imports			
		Gross S.S.			Flight	
	(1)	(2)	(3)	(4)	(5)	(6)
$SuddenStop(t=0)$	1.755***	−0.096	1.550**	−0.148	1.040	0.225
	(−0.083)	(−1.524)	(−0.700)	(4.837)	(0.915)	(2.525)
NFA_{t-1}	−1.004***	−1.421	6.019	0.063	−1.074	−1.278
	(0.230)	(−10.058)	(−5.442)	(0.543)	(0.830)	(0.842)
ERA_t	12.373***				12.587***	12.771***
	(−0.558)			(0.214)	(2.208)	(2.201)
-						
	(0.184)					
$HMLOC_t$		0.769*				
		(0.449)				
$HXLOC_t$			−4.733***			
			(0.300)			
–						
				(0.285)		
–						
–						
–						
$SuddenStop(t=0)*HX$	−3.096***					
	(−0.191)					
$SuddenStop(t=0)*HMLOC_t$		2.682				
		(5.031)				
$SuddenStop(t=0)*HXLOC_t$			−10.502***			
			(2.445)			
$SuddenStop(t=0)*HL$				0.969		
				(165.649)		
$SuddenStop(t=0)*NFA_{t-1}$					−0.491	0.525
					(1.240)	(1.341)
$SuddenStop(t=0)*ERA$						
$SuddenStop(t=0)*HM$					−2.056	−1.901
					(1.469)	(1.467)
$SuddenStop(t=0)*GOV$						0.356
						(0.358)
$SuddenStop(t=0)*INSOL$						−0.028*
						(0.015)
Observations	1,646	183	183	1,155	1,646	1,646
R^2	0.240	0.638	0.656	0.249	0.257	0.277
Adjusted R^2	0.162	0.291	0.328	0.166	0.166	0.180

Note: *p<0.1; **p<0.05; ***p<0.01.All regressions include quarterly period dummies, country fixed effects, and quarterly data seasonally adjusted.

Table 11: Correlations of Related Variables

	HX_i	HM_i	$HXLOC_i$	$HMLOC_i$	HL_i	WL_i
HM_i	0.94	.	.	.	.	.
$HXLOC_i$	0.62	0.65	.	.	.	.
$HMLOC_i$	0.38	0.46	0.83	.	.	.
HL_i	0.44	0.52	0.66	0.46	.	.
WL_i	0.58	0.66	0.49	0.31	0.53	.
NFA_i	-0.08	-0.15	-0.29	-0.27	-0.33	0.3

C Numerical Solution Method

The solution will be the series of endogenous and exogenous state variables, $\{x_t, z_t\}_{t=0,...,\infty}$, that together satisfy the system of equations 58 and 59. These are together the set of first order conditions and relationships $\tilde{Z}(.)$ that define the transition of state variables from one period into the next. We let the function $Y\left(x_t, z_t\right) = y_t$ determine the static choice variables in time t.

$$0 = E_t\left(x_t, z_t, x_{t+1}, z_{t+1}\right) \tag{58}$$

$$z_{t+1} = \tilde{Z}\left(z_t, \epsilon_{t+1}\right) \tag{59}$$

Here ϵ_t is the vector of exogenous shocks in this model. To get a starting point for the solution, we solve a second order perturbation in *Dynare* for each of the possible 'worlds' of the model, i.e. we need four model solutions up to a second order: when (1) $\sigma_1 > 0$, $\sigma_2 > 0$, (2) $\sigma_1 > 0$, and $\sigma_2 = 0$, (3) $\sigma_1 = 0$, $\sigma_2 > 0$ and (4) (2) $\sigma_1 = 0$, $\sigma_2 = 0$. We then splice the solutions together following Maliar and Maliar (2015). This provides a full series of x_t and z_t, on which we calculate the starting values x_0 and z_0 as the averages of endogenous and exogenous variables from the splice solution. Then we choose a simulation length T and construct a fixed set of exogenous forcing variables $(z_{t+1})_{t=0}^{T-1}$. Using a 3rd degree polynomial and set of initial coefficients b_0, we parameterize the policy function $\hat{X}_t$ that is an approximation of the true policy function $X\left(x_t, z_t, b_t\right) = x_{t+1}$. From this starting point we follow (Judd et al., 2011) in the following steps,

- **1. Construct the grid**: using the coefficients b_t, we simulate the model forward T periods to generate $\{x_t, z_t\}_{t=0,...,T}$, and then we construct an 'M-Cluster' grid following Judd et al. (2011) by carefully choosing M points from the distribution of simulated state variables, $\{x_t, z_t\}_{t=0,...,M}$.
- **2. Solve for the policy functions**: We approximate the expectations operator in Equation 58 with a set of Gauss-Hermite monomial weights and nodes for all points $m = 1, ..., M$,

$$\sum_{j=1}^{J} \omega_j G\left(x_{m,t}, z_{m,t}, x_{m,t+1}, z_{m,t+1}\ \right) = 0 \tag{60}$$

but we replace $x_{m,t+1}$ with $\hat{X}\left(x_{m,t}, z_{m,t}\right)$, and $z_{m,t+1}$ with $\tilde{Z}_t\left(x_{m,t}, \epsilon_{t+1}\right)$. We then solve for b_t up to a tolerance level of τ_h.

- **3. Iterate**: Repeat steps 1 and 2 until the cluster grid converges with a tolerance of τ_g

To handle the multiple constraints in this framework, we substitute out the Lagrange multipliers following Zangwill and Garcia (1981) with a smooth function function that is differentiable up to degree $k-1$. The parameter k smooths the discontinuous max function. A pair of complementary slackness conditions in a scalar x can be written

$$\begin{aligned} A(x) &\leq 0 \\ B(x) &\leq 0 \\ A(x)B(x) &= 0 \end{aligned}$$

This can be reformulated as

$$A(x) + (max\{0, \zeta\})^k = 0 \quad (61)$$

$$B(x) + (max\{0, -\zeta\})^k = 0 \quad (62)$$

Therefore we have a system of two equations and two unknowns, x and ζ. For example, from equation 17, $A(x) = V_t - \Gamma y_t^I Q_t$ and the Lagrange multiplier χ_t must satisfy $B(x) = \chi_t$. For the incentive constraint problem we define $a(\zeta)^+ = (max\{0, \zeta\})^k$ and $a(\zeta)^- = (max\{0, -\zeta\})^k$. Then we can write the two constraints and Lagrange multipliers as

$$\begin{aligned} a(\zeta_h)^- &= \chi_t \\ a(\zeta_f)^- &= \mu_t \\ a(\zeta_h)^+ &= V_t - \Gamma y_t^I Q_t \\ a(\zeta_f)^+ &= B_{t+1}Q_t + \kappa (K_{t+1} - \phi W_t L_t) \end{aligned}$$

We set the model simulation length to $T = 10,000$, Clusters are set to $M = 600$, and the convergence criterion on grid and expectational coefficients are set to $\tau_g = 1E - 4$ and $\tau_h = 1E = 5$, respectively. Using a personal laptop with Core i7 2.9 GH processor, and without using MatLab Parallel Computing Toolbox, a solution is found within .41 hours.

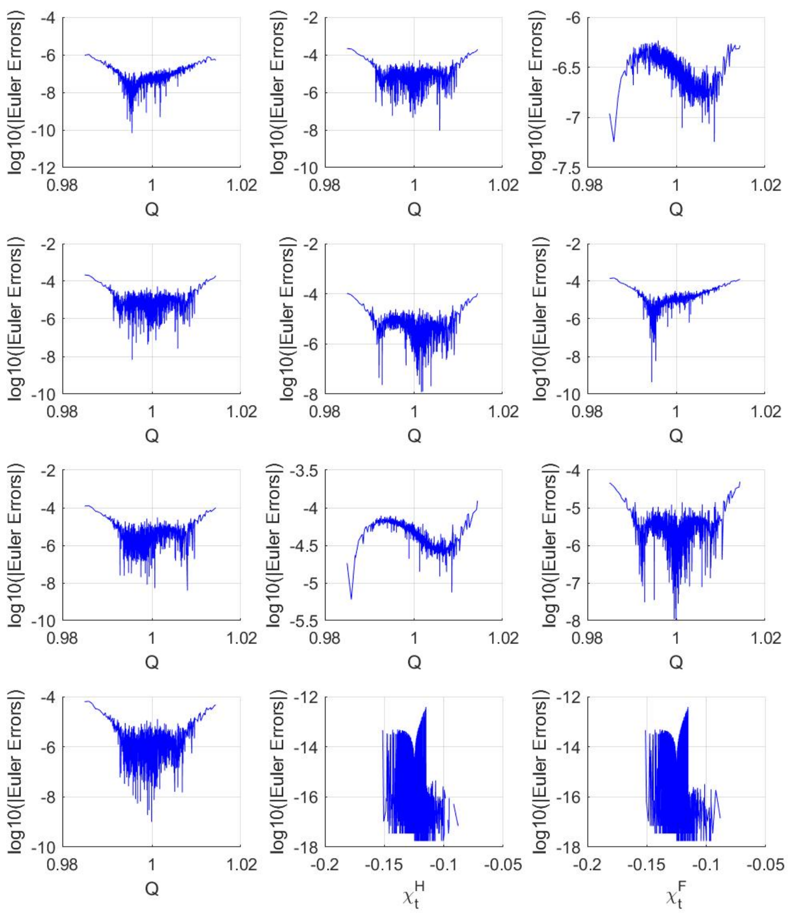
C.1 Accuracy of the Solution

To assess the accuracy of the solution, we construct a test series of length 1000, $\{x_{t,\tau}, z_{t,\tau}\}_{t=1,\ldots,1000}$, by simulating the model forward period. Then a new set of test integration nodes and weights, ϵ_τ and ω_τ are constructed, and finally, using (63), errors are computed $\varepsilon(x_\tau, z_\tau)$, by recomputing $G(.)$ over the test node and weights.

$$\varepsilon(x_{\tau,t}, z_{\tau,t}) = \sum_{j=1}^{J} \omega_j G(x_{\tau,t}, z_{\tau,t}, x_{\tau,t+1}, z_{\tau,t+1}) \quad (63)$$

We then take the maximum values of $\varepsilon(x_{\tau,t}, z_{\tau,t})$ over the test grid for the values of the exogenous shocks, and report the value graphically in Figure 12. The solutions accuracy is standard on the order of -4 log10. The variables χ_t^h and χ_t^f correspond the variables substituting out the Lagrange multipliers for the household and firm constraints. Q_t is the real exchange rate.

Figure 12: Residuals for Euler Equations



(a) We compute the residuals of the Euler equations following Judd (1992).

D Correlation of Invoicing and the Chance of a Sudden Stop

This section does not try to assign causation, rather we draw out the correlation that countries with more foreign currency invoicing will experience a sudden stop more often. We can substantiate this by running a simple linear cross section regression across the countries in our sample, indexed by i:

$$\text{(Share of Time in a Sudden Stop)}_i = \alpha + \beta X_i + HM_i + \epsilon_i \tag{64}$$

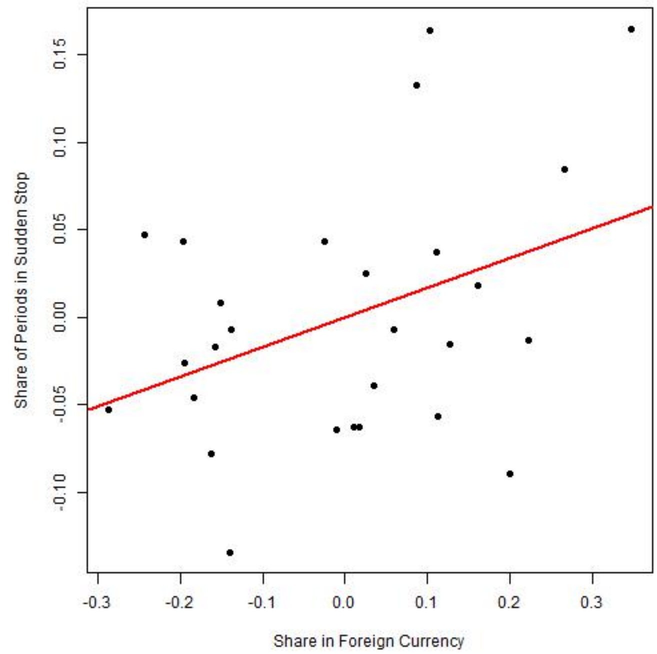
The X_i are country level controls, α is the intercept and HM_i is the average share of traded goods invoiced in domestic currency. Using just WL_i (share of domestic assets in home currency) as a control variable, the table below shows the result that indeed, countries with more trade in a foreign currency spend more time in a sudden stop. For a visual, we also plot the plot the partial regression of 'Share of Imports invoiced in a Foreign Currency' on 'Share of Time in a sudden stop' in Figure 13.

	Share of Time in Sudden Stop
Share of Imports in Foreign Currency	0.170^{***} (-0.011)
Domestic Liabilities in Foreign Currency	0.143^{***} (-0.022)
Observations	27

Note: *p<0.1; **p<0.05; ***p<0.01, with robust standard errors. Adjusted $R^2 = .17$

Many papers delve deeply into the causes for the severity, duration or frequency of sudden stops (Cavallo, Powell, Pedemonte, and Tavella (2015), Calvo et al. (2003), Forbes and Warnock (2011), etc.). It is a complex problem, and here we do not pretend that we doing something similar. Rather, none of the papers in that literature consider currency of invoicing, and here we argue that it might be worth considering.

Figure 13: Foreign Currency Invoicing Correlated with Sudden Stops



E Finding Sudden Stops in the Data

To construct a proxy for monthly net private inflows (P_t), the Calvo-method is to subtract changes in international reserves from the quarterly current account balance. Define C_t as a 12 month moving sum of lagged values and the year over year changes in P_t. A marked slow down in this measure of net capital flows will be the first period of a stop.

$$C_t = \sum_{i=1}^{11} P_{t-i} \qquad \text{t = 1, 2,...,N}$$

$$\Delta C_t = C_t - C_{t-12} \qquad \text{t = 13, 14,...,N}$$

A sharp slow down is defined as a period when capital flows do the following: (1) fall below one standard deviation of their historic mean; and (2) have at least one month where ΔC_t falls two standard deviations below its mean. The stop ends when flows return to within one standard deviation of the mean. There are popular deviations on this framework,[19] but in our efforts here, adding in other ingredients to the criteria have only a minimal effect on the Calvo-method results.

Then, according to the Forbes-method, a sudden net decrease in flows can arise from either a stop in inflows *or* a sharp increase in outflows, and almost surely, the factors causing one or the other are distinct. Using their definitions, *Sudden Flight* is when gross capital outflows increase sharply, and *Gross Stops* are when gross capital flows decrease suddenly.

[19] For example, having the requirement to have a drop in GDP growth-rates over the quarters identified by the first three criteria, or requiring at least two period of reduced flows (Calvo & Talvi, 2005a).

The principle difference here is that actual, quarterly data on capital flows is used, rather than a monthly proxy derived from changes in international reserves (as with the Calvo-method). But similar to Calvo et al. (2003), nearly identical criteria must be met. Table 12 provides summary statistics for each of the types of sudden stops defined so far. Our principal focus will be on net stops, however, reassuringly we'll see the results change little between definitions used. Table 8 in the Appendix provides a full list of all the sudden stops identified and used for this paper. Finally, we provide a visual of several net sudden stops in Thailand in Figure 11 of the Appendix.

Table 12: Sudden Stops and Flights

Var	Net S.S.	Gross S.S.	Gross Flight
Duration (Q)	2.510	3.710	3.570
Average Number per Country	3.930	2.830	2.810
Chance of being in a Sudden Stop (%)	4.590	6.020	5.770

F Alternative Capital Adjustment Costs

We also run the model with capital that is owned directly by the consumer, and rented directly to the firm. This simplifies the model a bit while maintaining all of the richness of before. We instead use the capital adjustment cost function,

$$f\left(\frac{I_t}{K_{t-1}}\right) = \frac{\xi_k}{2}\left(\frac{I_t}{K_{t-1}} - \delta\right)^2 \tag{65}$$

and the first order condition from the consumer's problem is,

$$q_t\left(1 - \kappa\frac{\mu_t}{\lambda_t}\right) = \tilde{\beta}E_t\left(\Omega_{t+1}\left[q_{t+1}\left(1-\delta\right) + r^k_{t+1} + f\left(\frac{I_{t+1}}{K_t}\right) - f'\left(\frac{I_{t+1}}{K_t}\right)\frac{I_{t+1}}{K_t}\right]\right). \tag{66}$$

and the price of capital is standard.

$$q_t = 1 + f'\left(\frac{I_t}{K_{t-1}}\right) \tag{67}$$

A note here on the solution method. To ensure that the solution is stable, we employ an endogenous discount factor

$$\tilde{\beta} = \left(1 + C_t - \eta\frac{L_t^{\omega}}{\omega}\right)^{\tilde{\phi}} \tag{68}$$

as is common in the literature on small open economies, and similar to the formulation of Mendoza (1991). We slowly reduce the value of ϕ while the solution describe here in the appendix continues to iterate over increasingly stable and accurate solutions. In this way, the model is solved while being free from dynamics-limiting exogenous and ad-hoc stabilizing fixes.