Exchange Rates and the Working Capital Channel of Trade Fluctuations

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Global value chains (GVCs) figure prominently in global trade and lie at the intersection of two important themes. The first is the financing requirement for working capital. The second is the prevalence of dollar invoicing in global trade.

The upshot of the interaction of these two themes is that the dollar exchange rate emerges as a determinant of GVC activity. Specifically, a stronger dollar is associated with tighter credit conditions and subdued GVC activity. As a result, exports from an emerging economy may fall when its currency depreciates against the dollar. Our paper highlights this financial channel of the dollar on global trade.

In Thomas Friedman's book *The World is Flat*, a logistics executive is quoted as saying "[w]hen our grandfathers owned shops, inventory was what was in the back room. Now it is a box two hours away on a package car, or it might be hundreds more crossing the country by rail or jet, and you have thousands more crossing the ocean." [Friedman (2005, p.174)]

The picture of boxes whizzing around the world is a marvel not only of modern communications but also of finance, as those boxes are inventories of the firm. On the balance sheet, they enter as assets and must be financed somehow. Long supply chains entail substantial financing needs, which increases in a non-linear way with the length of the supply chain.

To see this, consider an auto manufacturer with plants in Japan, Canada and Mexico. The firm makes engines in Japan and ships it to its plant in Canada, where it undergoes further assembly. The semi-finished car then goes to Mexico where it is finished. At any given date, the firm carries three pieces of inventories - the engine, semi-finished car and the finished car.

The three pieces of inventory differ in value, reflecting past value-added. Suppose, for simplicity, that the engine has value w, the semi-finished car has value $2w$ and finished car has value $3w$. In this example, financing need increases at the rate of the *square* of the length of the supply chain, as the total value of inventories at any moment in time is the sum $w + 2w + 3w$.

If the GVC crosses the boundary of the firm, the working capital needs show up as accounts receivable, not inventories, but the principle is the same. Financing needs for working capital increase rapidly with the length of the GVC.

Given their financing requirements, long, elaborate GVCs are sustainable only with plentiful financing. Anil Kashyap, Owen Lamont and Jeremy Stein (1994) show that inventories of firms that depend more on external financing fall more sharply in response to a contraction in credit supply.

Our contribution is to extend these insights to a global context where dollar credit conditions take on a central role due to the prevalence of dollar invoicing in global trade (Gita Gopinath (2015) and Gopinath and Stein (2017)). The Bank for International Settlements (2014) estimates that globally, around 80 percent of bank trade credit is denominated in US dollars.

The upshot of the global role of the dollar in trade finance is that the dollar exchange rate affects not only the competitiveness of exports but also affects credit conditions for working capital. We build on the literature on the *risk-taking channel of exchange rates* due to Bruno and Shin (2015a, b), where a stronger dollar is associated with tighter dollar credit conditions. The mechanism is as follows. In the presence of currency mismatches on borrowers' balance sheets, a weaker dollar flatters the balance sheet of dollar borrowers, whose liabilities fall relative to assets. From the standpoint of bank creditors,

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the stronger credit position of borrowers reduces tail risk in a diversified credit portfolio of dollar loans and creates spare lending capacity by relaxing the Value-at-Risk (VaR) constraint. An immediate implication is that the broad dollar index is the relevant exchange rate for this channel.[1]

Our empirical hypothesis is as follows. In an environment of long GVCs fostered by a long period of easy dollar credit conditions, the tightening of dollar credit associated with a stronger dollar will curtail GVC activity. Our hypothesis complements the invoicing explanation in Camila Casas, Federico Diez, Gita Gopinath, and Pierre-Olivier Gourinchas (2016) for why a stronger dollar may result in weaker global trade. In our empirical exercise, we use balance sheet proxies for the length of GVCs to highlight the risk-taking channel of exchange rates, linking the working capital demands of GVCs to the fluctuations of the US dollar exchange rate.

I. Benchmark "Austrian" Model

Before introducing the invoicing role of the dollar, we develop intuition on working capital in a closed economy context following Kim and Shin (2013).

Suppose there are L workers, each matched with one of L plants. Plants are organized into production chains of length n in which the output of plant k is the input to plant $k-1$, and each step in the production process takes one unit of time. Total revenue of a chain of length n is

$$y(n) = n^{\alpha} l, \qquad (0 < \alpha < 1) \tag{1}$$

where l is total labor employed by the chain.

This formulation of production echoes Eugen Böhm-Bawerk's (1884, p. 88) notion of "roundabout production" where intermediate goods are used as inputs and where "[t]he indirect method entails a sacrifice of time but gains the advantage of an increase in the quantity of the product. Successive prolongations of the roundabout method of production yield further quantitative increases though in diminishing proportion."

[1]Stefan Avdjiev, Bruno, Catherine Koch and Shin (2017) show that the broad dollar index acts as a global risk factor that affects real investment, while Avdjiev, Wenxin Du, Koch and Shin (2016) show that the deviation from covered interest parity is also explained by the broad dollar index.

Labor is provided inelastically. Wage is w, and cannot be deferred. There is no physical capital. Cashflows are given in Figure 1. The first positive cashflow to the chain comes at date $n+1$ when firm 1 sells the final output for $y(n)$.

Working capital is needed to finance the accumulated "triangle" of wage costs:

$$\tfrac{1}{2} n (n+1) w \tag{2}$$

Since there are L/n production chains, the aggregate financing requirement in the economy, denoted by K, is

$$\begin{aligned} K &= \tfrac{1}{2} n (n+1) w \times \frac{L}{n} \\ &= \tfrac{1}{2} (n+1) wL \end{aligned} \tag{3}$$

Consider the social planner's problem, which is to choose n to maximize steady state surplus:

$$\begin{aligned} \Pi &= n^{\alpha} L - wL - rK \\ &= n^{\alpha} L - wL \left(1 + \tfrac{r(n+1)}{2}\right) \end{aligned} \tag{4}$$

where r is the financing cost. The first-order condition for n gives

$$n = \left(\frac{2\alpha}{wr}\right)^{\frac{1}{1-\alpha}} \tag{5}$$

We close the model with the zero profit condition: $n^{\alpha} = w(1 + r(n+1)/2)$. Optimal chain length n can be solved in closed form as

$$n = \frac{\alpha}{1-\alpha}\left(\frac{2}{r} + 1\right) \tag{6}$$

implying that n is decreasing in financing cost r. Output per worker is

$$\left(\frac{\alpha}{1-\alpha}\right)^{\alpha}\left(\frac{2}{r} + 1\right)^{\alpha} \tag{7}$$

which declines in r, reflecting shorter chain length. The wage w is

$$w = 2\left(\frac{\alpha}{r}\right)^{\alpha}\left(\frac{1-\alpha}{2+r}\right)^{1-\alpha} \tag{8}$$

so that w also declines in r. Total credit for

		Firms					Cumulative cashflow
		1	2	$\cdots$	$n-1$	n	
date t	1					$-w$	$-w$
	2				$-w$	$-w$	$-3w$
	$\vdots$			$\cdots$	$-w$	$-w$	$\vdots$
	$n-1$		$-w$	$\cdots$	$-w$	$-w$	$-\frac{1}{2}(n-1)nw$
	n	$-w$	$-w$	$\cdots$	$-w$	$-w$	$-\frac{1}{2}n(n+1)w$
	$n+1$	$y(n)-w$	$-w$	$\cdots$	$-w$	$-w$	
	$\vdots$	$\vdots$	$\vdots$		$\vdots$	$\vdots$	

FIGURE 1. CASHFLOWS IN PRODUCTION CHAIN

working capital is

$$\begin{aligned} K &= \tfrac{1}{2}(n+1)\,wL \\ &= \left(\tfrac{\alpha}{1-\alpha}\right)^{\alpha}\left(\tfrac{2}{r}+1\right)^{\alpha}\left(\tfrac{\alpha}{r}+\tfrac{1-\alpha}{2+r}\right)L \end{aligned} \tag{9}$$

We may interpret K as aggregate credit demand. The model can be closed by introducing a credit supply function $S(r)$ which is increasing in r. Setting (9) equal to credit supply gives us the market clearing r.

Anticipating the solution for r, we can take r as a proxy for the tightness of credit supply. The tighter are credit conditions, the shorter is the supply chain.

II. Working capital needs from offshoring

We now introduce dollar financing. Consider a multinational firm whose product has m stages of production, given exogenously. Assume also that there are m production locations, where each location has an absolute advantage in one stage of the production process. Revenue is assumed to be

$$\left(\textstyle\sum_{i=1}^{m} x_i\right)^{\alpha} \qquad (0<\alpha<1) \tag{10}$$

where $x_i = 1+b$ for constant $b>0$ if production of the ith stage takes place in the most favorable location, while $x_i = 1$ if the production takes place elsewhere. If the firm produces n stages of the production process in the best location for that stage, total revenue is

$$A(m,n) = (m+bn)^{\alpha} \tag{11}$$

The firm chooses n, the extent of offshoring**.**

Offshoring entails substantial working capital needs. Mary Amiti and David Weinstein (2011) note that shipping and customs delays can be as long as two months. To capture this feature, we assume that if an intermediate good is shipped to another location, transport takes one period of time, which is the same as the time needed for completing one step in the production process. Also for simplicity, assume that offshoring also entails labor input cost w. The firm meets working capital needs by borrowing in dollars at interest rate r.

Offshoring lengthens the time needed for production and entails higher financing needs. When production takes $m+n$ periods the demand for dollar credit, denoted by K, is

$$\begin{aligned} K &= \tfrac{1}{2}(m+n)(m+n+1)w\tfrac{L}{m+n} \\ &= \tfrac{1}{2}(m+n+1)\,wL \end{aligned} \tag{12}$$

where L is the world labor force. Per period profit is

$$\begin{aligned} \Pi &= (m+bn)^{\alpha}zL - wzL - rzK \\ &= (m+bn)^{\alpha}zL - wzL\left(1+\tfrac{r(m+n+1)}{2}\right) \end{aligned}$$

where z is the proportion of the world workforce employed by the firm. The firm chooses n to maximize Π. The first-order condition for n yields

$$m+bn = \left(\frac{2b\alpha}{wr}\right)^{\frac{1}{1-\alpha}} \tag{13}$$

and the zero profit condition is

$$(m+bn)^{\alpha} = w\left(1+\tfrac{r(m+n+1)}{2}\right) \tag{14}$$

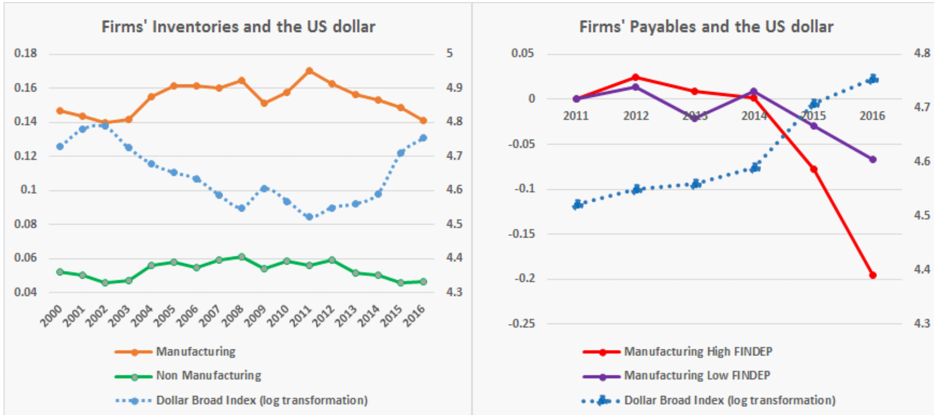

FIGURE 2. WORKING CAPITAL AND THE DOLLAR

From (13) and (14) we solve for n.

$$(15) \quad n = \frac{\alpha}{1-\alpha}\left(m + 1 + \frac{2}{r}\right) - \frac{1}{1-\alpha}\frac{m}{b}$$

We can also solve for the wage as a function of r, $w(r)$. Substituting (15) and $w(r)$ into (12) we obtain the demand for dollar credit $K(r)$ which is decreasing in r.

We close the model by introducing a supply function for dollar credit $S(d, r)$, which increases in r, but decreases in d, interpreted as the broad dollar index. Since dollar credit supply is decreasing in d, we conclude that n is decreasing in d. We summarize our result as follows.

PROPOSITION 1: *GVC length n is decreasing in the value of the dollar.*

III. The dollar and working capital: evidence from a panel of firms

We examine how the dollar co-moves with balance sheet proxies for GVC activity, such as inventories, accounts receivable and accounts payable. The sample covers a balanced panel of 2,505 non-financial firms in Asia (China, India, Indonesia, Malaysia, the Philippines, South Korea, Thailand, and Vietnam) for the period 2000-2016, using annual data from Capital IQ.

The left hand panel of Figure 2 plots the median reading of the growth in the inventories to total assets ratio (left axis), together with the broad US dollar index (right axis). A high reading of the dollar index indicates a strong dollar. We see that a stronger dollar is associated with slower growth of inventories.

The pattern in Figure 2 is confirmed in the panel regressions using firm-level data. As dependent variables, we take annual percentage changes in account receivables, payables, and inventories, all pre-normalized by total assets. The panel regressions include industry and country fixed effects. Standard errors (in brackets) are clustered at the 3 digit SIC code level.

The key explanatory variable is the change in the broad US dollar real effective exchange rate (*USD Broad*) from the BIS. A higher *USD Broad* indicates a stronger dollar. Control variables include sales growth, ratio of cash to total assets, cash flows to total assets, property plants and equipment to total assets. All explanatory variables are lagged by one year.

Table 1 shows that a one point increase in the broad dollar index is associated with a decline in the annual growth of accounts receivable by 0.28% (column 1), a decline in payables growth by 0.62% (not reported), and a decline in inventory growth by 0.40% (not reported). All are significant at the 1 percent level. When we use the bilateral exchange rate vis-à-vis the US dollar, the association between the dollar and the change in account receivables (column 2), payables and inventories is no longer statistically significant. This evidence confirms earlier studies that the broad US dollar index is the relevant exchange rate for the financial channel of exchange rates (Stefan Avdjiev, Wenxin Du, Catherine Koch and Shin (2017), Avdjiev, Bruno, Koch and Shin (2017)), as the broad dollar exchange rate best captures the financial impact of the exchange rate on global banks with a

TABLE 1—**WORKING CAPITAL AND THE US DOLLAR.**

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent variable			ΔReceivables			ΔPayables	ΔInventories
Sample	All	All	All	Manu	non-Manu	Manu	Manu
ΔUSD Broad	-0.2856		-0.2709	-0.2670	-0.3398	-0.6728	-0.3932
	[0.0640]		[0.0656]	[0.0764]	[0.1640]	[0.1213]	[0.0599]
ΔUSD Bilateral		-0.1002					
		[0.0716]					
ΔUSD Broad*FINDEP			-0.0589	-0.0597	-0.0323	-0.0530	-0.0226
			[0.0142]	[0.0134]	[0.1313]	[0.0300]	[0.0084]
Constant	0.1354	0.1358	0.3954	0.0188	0.3408	-0.1317	-0.0503
	[0.0159]	[0.0236]	[0.0182]	[0.0219]	[0.0309]	[0.0318]	[0.0115]
Observations	88,136	88,136	84,241	57,037	27,204	55,821	56,663

diversified global portfolio of dollar loans.

Next, we interact Δ*USD Broad* with an industry-level indicator of external financial dependence *FINDEP* due to Raghuram Rajan and Luigi Zingales (1998) to see whether firms with higher external financing needs are affected more by an appreciation of the US dollar.[2] The right hand panel of Figure 2 shows a preview of the results; it plots the changes in account payables, normalized to 2011 levels, for the subset of manufacturing firms divided into those with high financing needs and low financing needs (33 vs 66 percentile of *FINDEP*, left axis). We see that a stronger dollar (right axis) is indeed associated with a more marked decrease in payables for firms with high external financial dependence.

In the regression estimates, the coefficient on the interaction term Δ*USD Broad**FINDEP* is negative and statistically significant at the 1 percent level, suggesting that firms more dependent on external financing suffer a larger decrease in account receivables (column 3). When we split the sample into manufacturing (column 4) and non-manufacturing firms (column 5), the interaction term Δ*USD Broad**FINDEP* is significant only for manufacturing firms, lending weight to the hypothesis that GVC activity is affected by dollar strength. In terms of economic magnitude, a one point increase in the broad dollar index is associated with an additional decline in growth of account receivables by 0.03% for manufacturing firms that are dependent on external financing (66 vs. 33 percentile of *FINDEP*).

Similar results hold for accounts payable (column 6) and inventories (column 7).

Overall, we conclude the following. First, a strong dollar is associated with weak growth of balance sheet proxies of GVC activity. Second, the relevant exchange rate is the broad dollar index, in line with previous studies that have found that dollar lending by global banks fluctuates with the broad dollar index. Third, the working capital of manufacturing firms is affected more by a stronger dollar than non-manufacturing firms. We take these findings as evidence that for GVCs with high financing needs, a stronger dollar is associated with a tightening of dollar credit and a higher hurdle rate for GVC sustainability.

IV. Concluding Remarks

The philosopher René Descartes famously argued that the nature of the mind is distinct from that of the body, and that it is possible for one to exist without the other. Similarly, in debates about globalization, there is sometimes a tendency to draw a sharp distinction between real and financial openness, coupled with the claim that real openness, associated with trade and investment, can be achieved without financial openness. In practice, it turns out to be exceedingly difficult to prise apart real and financial openness. Global trade and the role of GVCs is a good example of this maxim.

The message of our paper is that, paradoxically, a weaker currency against the dollar may actually serve to dampen trade volumes, rather than stimulate them. Our findings complement the findings in Casas et al. (2016) that when trade between third countries is invoiced in dollars, a stronger dollar dampens exports. Our ex-

[2]We thank Stijn Claessens, Hui Tong, and Shang-Jin Wei for sharing their data series on financial dependence. Results are robust to the inclusion of firm fixed effects or clustering of standard errors at the firm level.

planation centered on financial conditions complements models where working capital incentive problems in acting as the "glue" that binds the components of global value chains - see Kim and Shin (2012) and Sebnem Kalemli-Ozcan, Kim, Shin, Bent Sorensen and Sevcan Yesiltas (2014).

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