What Drives Dollar Funding Stress in Distress?*

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We study the forces driving dollar funding stress under adverse market conditions for Asia-Pacific economies. We find that the response of dollar funding conditions to changes in macrofinancial variables differs significantly between orderly and turbulent markets. In orderly markets, idiosyncratic dollar strength, currency volatility, and monetary policy divergence are key factors affecting the stress for the economy. Currency expectations and FX market liquidity also play an important role in determining long-term funding pressure. In turbulent markets, the effect of these variables—except idiosyncratic dollar strength and currency volatility, which retain a strong influence—diminishes or even vanishes. Instead, the creditworthiness of the government and corporate sectors, which is found to have little impact under normal market conditions, emerges as a major stress determinant, and becomes increasingly influential as adversity intensifies.

JEL Codes: C31, E44, F31, G15.

1. Introduction

Social distancing measures have been an inevitable policy response in practically all countries in combating the spread of the COVID-19 virus. In cities and countries where the spread takes hold, the

*The authors are grateful to two anonymous referees for insightful comments. They also thank Adolfo Barajas, Tom Fong, Giorgio Valente, Eric Wong, and Jiayue Zhang for invaluable comments and discussions. Any remaining errors and the views expressed are the authors' own and do not represent those of the Hong Kong Monetary Authority, Hong Kong Academy of Finance, or Hong Kong Institute for Monetary and Financial Research. Author e-mails: ytang@hkma.gov.hk and alfred_yt_wong@hkma.gov.hk.

authorities have had no alternative but to enforce lockdowns, bringing all social activities to a standstill and paralyzing the economy. As a result, the world has slipped rapidly into an economic abyss, the deepest since the Great Depression in the 1930s.[1]

In view of the sharply deteriorating economic outlook for the United States and globally, the Federal Reserve eased monetary policy aggressively and took extraordinary steps to cushion the economy and provide sufficient liquidity for U.S. financial institutions and corporations.[2] Given the unrivaled role the U.S. dollar played in facilitating international finance and trade, the availability and adequacy of dollar funding were equally important for financial institutions and corporations outside the United States to weather the global health crisis. However, the actions of the Federal Reserve did not help them initially. Shortly after the announcement on March 11, 2020 by the World Health Organization (WHO) that the outbreak had evolved into a pandemic, a severe shortage of U.S. dollars quickly developed internationally, imposing significant dollar funding stress on the global economy (Avdjiev, Egemen, and McGuire 2020).

Dollar funding conditions have eased after the Federal Reserve reinvigorated its existing swap line arrangements with major central banks and introduced new ones with the central banks of some emerging markets.[3] However, although a global economic recovery is now under way, uncertainty still looms large given that the vaccination process is likely to take a protracted period of time while the virus continues to mutate. Adding to the uncertainty is the recent

[1]The global economy registered a dismal –3.3 percent growth in 2020 against the backdrop of what is sometimes referred to as the Great Lockdown (https://blogs.imf.org/2020/06/24/reopening-from-the-great-lockdown-uneven-and-uncertain-recovery/).

[2]The Federal Open Market Committee decided to lower the target range for the federal funds rate by 1/2 percentage point to 1 to 1-1/4 percent on March 3, 2020 (https://www.federalreserve.gov/newsevents/pressreleases/monetary20200303a.htm) and by 1 full percentage point to 0 to 1/4 percent on March 15, 2020 (https://www.federalreserve.gov/newsevents/pressreleases/monetary20200315a.htm).

[3]According to the Board of Governors of the Federal Reserve System (2020), the Bank of Canada, the Bank of England, the Bank of Japan, the European Central Bank, the Federal Reserve, and the Swiss National Bank have taken coordinated actions to enhance the provision of liquidity via the standing U.S. dollar liquidity swap line arrangements. In addition, the Federal Reserve has established temporary dollar liquidity swap lines with nine additional foreign central banks.

sharp escalation of the United States–China tensions over a wide range of geopolitical issues. Could this lead to a potential reduction in U.S. dollar supply globally or to some economies? Are we already in the run-up to more significant global financial turmoil than in March 2020 when the WHO declared a pandemic? There seems to be a pressing need for policymakers to understand better the driving forces behind dollar funding stress so that they can be more prepared when the next crisis hits. This is particularly true for Asia Pacific, given the region's considerably larger share of economic activity accounted for by global supply chains and its traditionally stronger demand for dollar funding and higher funding cost sensitivity (Hong et al. 2019).

Research on the driving forces behind dollar funding stress is not new. However, much of it is focused on explaining what causes or sustains it—in particular, why the phenomenon has persisted for years after the 2007/08 global financial crisis and the European debt crisis (Baba and Packer 2009b; Ivashina, Scharfstein, and Stein 2015; Borio et al. 2016; Sushko et al. 2017; Du, Tepper, and Verdelhan 2018). No study has so far attempted to identify the forces in crisis times. Also, the spotlight of the research always follows the major currencies, especially those in Europe. However, the dollar also plays an undisputable and dominant role as the primary reserve currency, cross-border financing currency, and cross-border trade invoicing currency in Asia Pacific.[4] The importance of the potential implications has made EMEAP (2020) turn the spotlight to the region with an intention to better understand the role of the dollar in cross-border financing activities and its impact on financial stability.

This paper contributes to the literature as a first attempt to study the dynamics of these forces under extreme market situations, focusing on eight EMEAP economies. We first examine the normal market relationship between dollar funding stress and a number of potentially determining factors, leveraging on the findings of

[4]In addition, according to EMEAP (2020), around 70 percent of outstanding international debt securities and more than half of banks' cross-border claims and liabilities in the region are denominated in U.S. dollars at end-2019. EMEAP stands for the Executives' Meeting of East Asia-Pacific Central Banks, a forum launched in 1991 to strengthen the cooperative relationship among central banks in the East Asia and Pacific region (https://www.emeap.org/).

previous studies. We then estimate the distressed market relationship between them to uncover any behavioral changes.

Interestingly, we find that bilateral dollar strength, rather than the strength of the dollar globally, plays a much more important role in determining dollar funding stress for the economies in the region, a result that is in contrast with Avdjiev et al. (2019), who find that idiosyncratic currency strength plays, if any, a passive role. Currency volatility, currency expectations, and foreign exchange (FX) market liquidity, which reflect various risks pertaining to dollar strength on a bilateral basis, and monetary policy divergence between the United States and the economy concerned also contribute to the stress. However, these drivers, except idiosyncratic currency strength and currency volatility, are left on the back burner by the dollar lender in extending credit in financial turmoil, especially under the most extreme scenario. Instead, the credit risk of the government and corporate sectors, which has little impact on both the short- and long-term stress during normal market times, emerges as a primary consideration for the dollar lender in turbulent markets. This suggests that borrowers from economies with a weaker fiscal position or higher corporate debt may face greater challenges in dollar funding markets in crisis times. Overall, the results are more aligned with those of the studies that emphasize currency volatility (Liao and Zhang 2020) and credit channels (Hartley 2020; Liao 2020).

The rest of the paper is organized as follows. In the next section we explain and define what we mean by dollar funding stress. Section 3 discusses the potential factors driving dollar funding stress. In Section 4 we set out the model, its specifications, and the data used for estimation. Section 5 presents and discusses our results. Section 6 concludes the paper with a brief discussion of the policy implications.

2. What Is Dollar Funding Stress?

Cost of USD borrowing per se should not be taken to mean or reflect dollar funding stress. Otherwise, most funding markets would have registered a reduction, rather than an increase, in the stress at the peak of the outbreak in early 2020. For example, the three-month USD LIBOR, the cost of borrowing in the interbank money market, in fact fell substantially, but the fall was mainly attributed to the large reductions in the target federal funds rate by the Federal

Reserve in March 2020.[5] It is also debatable to label larger spreads of the LIBOR over its respective overnight indexed swap (OIS) rate as evidence for higher dollar funding stress. As OIS is practically risk-free, the LIBOR-OIS spread reflects mostly the premium the lender charges for lending on an uncollateralized basis.[6] Other things being equal, this premium would thus increase as the economic environment deteriorates and vice versa. True, when the premium increases, it pushes up the LIBOR, the total cost of USD borrowing. However, a higher cost resulting from a larger premium to compensate the lender for taking a higher risk is not what the stress refers to here.

Dollar funding stress refers to what is above and beyond the cost of borrowing in the LIBOR market. The interest rates that matter to the borrower are the ones at which he can borrow. The well-known problem with the LIBOR market is that it is not a market that is always accessible to all.[7] For those shut out of the interbank money market in times of financial turbulence, the LIBOR is simply irrelevant. Under these circumstances, it is the market they turn to which matters. And the most popular alternative for them is probably the cross-currency swap market, in which they could swap their domestic currency for U.S. dollars, effectively borrowing U.S. dollars by pledging another currency as collateral.

The more stressful the situation is, the more financial institutions and corporations would be forced to resort to the market for USD funding. Other things being equal, this would push up the cost of USD borrowing in the cross-currency swap market. Theoretically, the cost of borrowing should equalize across markets under covered interest parity. Any difference in the borrowing cost between the LIBOR and cross-currency swap markets cannot sustain even for minute periods of time, as traders and other market participants

[5]The LIBOR, the London interbank offered rate, remains the most popular benchmark cost of borrowing in the interbank money market despite its widely known problems (King and Lewis 2020).

[6]A LIBOR transaction is one in which a party lends to another without any collateral, but an OIS—an interest rate swap between a fixed rate and a predetermined floating daily overnight rate—is a transaction that does not involve lending or exchange of principals.

[7]This may be best exemplified by the difficulties experienced by European financial institutions during the 2007/08 global financial crisis (Baba and Packer 2009b).

would arbitrage it away. However, following the 2007/08 global financial crisis, the pressure has grown so much that the cost of borrowing U.S. dollars in the cross-currency swap market now often exceeds that in the interbank money market, making possible material violations to the parity condition.

The resulting deviation, which often occurs in favor of the U.S. dollar, is widely interpreted as an indication of how much the market is under stress in its hunger for U.S. dollars.[8] The level of stress can thus be measured by the deviation, that is, the extent to which the cost of USD borrowing in the cross-currency swap market exceeds the cost of USD borrowing in the interbank money market. For short-term dollar funding, the dollar funding stress can be measured by the FX swap basis, which is the difference between the USD LIBOR and the implied USD interest rate in the FX swap transaction. For long-term dollar funding, it can be gauged directly by the basis traded in the cross-currency basis swap (CCBS) market.[9] The more negative the FX swap or CCBS basis, the greater is the USD shortage and the higher is the dollar funding stress.

In March 2020, the three-month FX swap basis increased 100 basis points for the Japanese yen, 54 for the euro, 63 for the British pound, and 91 for the Swiss franc within one week following the WHO announcement, while the five-year CCBS basis widened 13 basis points for the Japanese yen, 4 for the euro, 5 for the British pound, and 6 for the Swiss franc. In emerging Asia, economies also took a similar beating, reaching levels unseen in recent years (Figures 1 and 2). The same week saw, for instance, the three-month FX swap basis rise 266 basis points for the Singapore dollar, 9 for the Hong Kong dollar, and 161 for the Korean won, whereas there was

[8]There are, however, competing theories arguing that when counterparty credit risk is present (which is the case after the global financial crisis, as evidenced by the LIBOR-OIS spread for most currencies), the deviation merely reflects that interest rates for unsecured lending/borrowing are no longer appropriate for pricing the secured transactions in cross-currency swap markets (Wong and Zhang 2018).

[9]In both cases, the counterparty credit risk involved in the transaction is minimal, as the USD borrowing party needs to pledge another currency as collateral. At the same time, the funding liquidity risks of the two parties are swapped, where the USD lending party takes the funding liquidity risk of USD while the USD borrowing party takes the funding liquidity risk of the other currency.

Figure 1. Three-Month FX Swap Bases of EMEAP Currencies, Jan. 2017–Mar. 2021

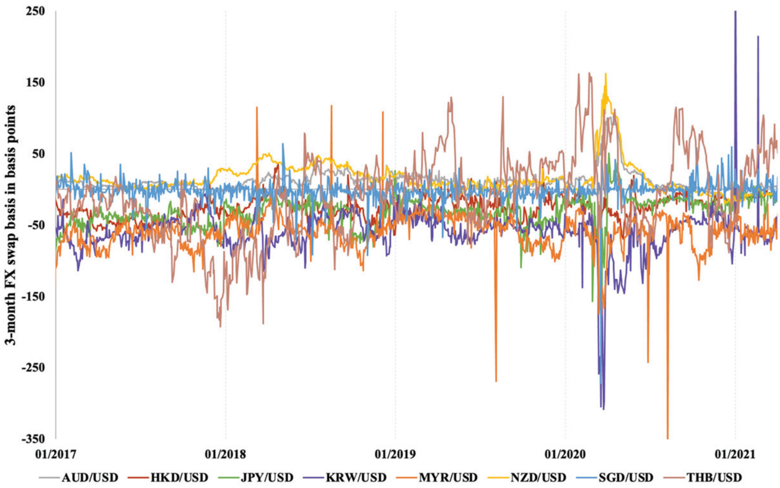
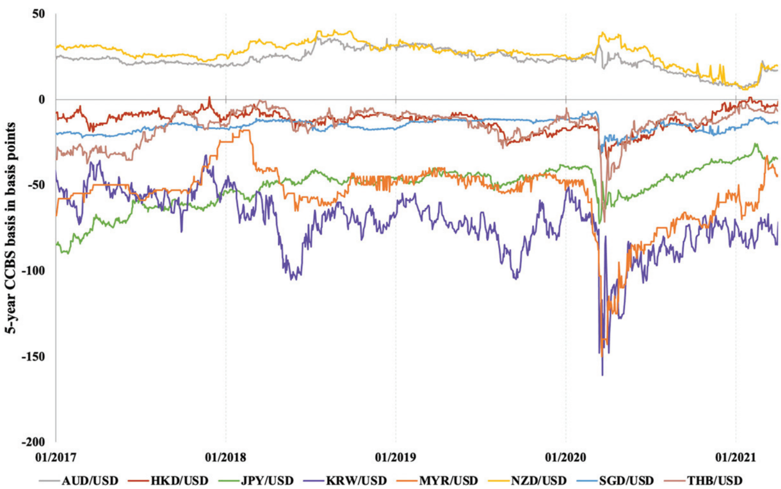


Figure 2. Five-Year CCBS Bases of EMEAP Currencies, Jan. 2017–Mar. 2021



a widening of the basis by 17, 10, and 72 basis points, respectively, for these currencies in the CCBS market.

3. Potential Driving Forces of Dollar Funding Stress

Cross-currency bases for most currencies vis-à-vis the U.S. dollar are in favor of the lender of U.S. dollars. It is common to see, for example, in CCBS transactions, that the dollar-lending party effectively borrows foreign currency at a discount to the foreign currency LIBOR and this discount is the basis. There are only a few exceptions where the deviations are in favor of the foreign currency lender, e.g., the Australian dollar and the New Zealand dollar.[10] However, apart from these rare cases, the fact that the higher implied dollar interest rates compared with the LIBOR in cross-currency swap transactions are generally taken as a sign of global shortage of U.S. dollars and, hence, also the amount of stress associated with the shortage.

Since the covered interest parity condition broke down following the onset of the global financial crisis in 2007/08, a large volume of literature has surfaced, offering a wide range of explanations and theories about the phenomenon. This study is not another attempt to add more explanations or theories to the debate or argue which explanation or theory is more credible. Instead, we wish to take into account the existing explanations and theories and adopt a more pragmatic approach to tackling the question by examining the potential driving forces empirically. Consequently, we consider the candidates for which data, especially daily data, are available.[11] We have identified the following list of variables and discuss each of them briefly below.

- *Global Dollar Strength.* Avdjiev et al. (2019) find the global strength of the U.S. dollar to be an important driving force

[10]In addition, there are a small number of other currencies, such as the British pound, whose cross-currency bases occasionally reverse themselves although they are on balance in favor of the dollar.

[11]As a result, institutional factors that may aggravate or contain the stress such as central bank swap lines are not considered, although the effect of these factors would filter through to some of the macrofinancial variables in the list below (Bahaj and Reis 2018).

behind the currency swap bases for major currencies, as the effect of a stronger dollar feeds through to the shadow price of cross-border bank leverage for non-U.S. financial institutions. This study employs the same proxy they use for global dollar strength, the broad dollar index vis-à-vis the currencies of a large group of U.S. trading partners compiled by the Federal Reserve Board.

- *Idiosyncratic Dollar Strength.* By the same token, the strength of the dollar vis-à-vis the currency concerned may arguably be a more relevant shadow price for the financial institutions in the economy concerned. Idiosyncratic dollar strength here refers to the strength of the dollar against the currency not attributable to the global strength of the dollar. It is represented by the residual obtained by regressing the bilateral exchange rate of each of the currencies vis-à-vis the U.S. dollar (indexed to share the same base with the broader dollar index) on the broad dollar index.[12]
- *Currency Volatility.* If dollar strength affects the shadow price of cross-border bank leverage, the risk to its stability would naturally be a source of concern. This price is likely to increase in times of market turbulence as hedging demand grows and the use of FX derivatives intensifies (Liao and Zhang 2020). Consequently, other things being equal, higher currency volatility may result in a higher price premium to pay for the certainty of the cost of dollar funding.
- *Currency Expectations.* Similarly, the expected appreciation (or depreciation) of the exchange rate of the U.S. dollar vis-à-vis the currency concerned is also likely to play a role. The risk reversal of the currency, which is the difference in implied volatility between the call and put currency options, is used to proxy currency expectations.[13]

[12] We have also used the bilateral exchange rate instead of the idiosyncratic dollar strength in our estimation. The results, which can be available upon request, are similar.

[13] The price of an option reflects the market expectation of the likelihood of an adverse outturn happening. A call option gives the right to buy the asset at a certain price and a put option offers the right to sell. Hence, the buyer of a call bets on the asset to rise above the strike price within a certain period, while the seller thinks it may not and accepts a payment for taking the risk. A put

- *FX Market Liquidity.* Arai et al. (2016) argue that regulatory reforms make global banks less reluctant to engage in market making and arbitrage trading in the FX swap market, while Krohn and Sushko (2020) find that deterioration in dollar funding is linked to a reduction in market liquidity in the spot FX market. It is thus reasonable to consider bid-ask spreads in both the spot and forward markets as potential candidates.
- *Financial Market Volatility.* Stock market volatility is often regarded as a signal of global banks' leverage cycle that drives cross-border fund flows and hence global liquidity conditions (Borio and Disyatat 2011; Forbes and Warnock 2012; Obstfeld 2012a, 2012b; Bruno and Shin 2015; Rey 2015). We adopt the widely used forward-looking S&P 500 volatility measure as a gauge of market risk or "fear" to capture the impact of market sentiment on dollar funding conditions (Whaley 2000; Giot 2005).
- *Interest Differential.* Arai et al. (2016) observe that corporate borrowers tend to arbitrage any interest differential by issuing bonds denominated in currencies with a lower yield to hedge their proceeds back via FX swaps, thus putting upward pressure on the higher-yielding currency in the cross-currency swap market. Du, Tepper, and Verdelhan (2018) also find that cross-currency bases tend to be positively correlated with the level of nominal interest rates and increase with interest rate shocks.
- *Monetary Policy Divergence.* A larger "interest margin" or steeper yield curve for a currency is more conducive to funding investment denominated in the currency by other currencies (with a smaller "interest margin" or a flatter yield curve) through the cross-currency swap market, causing a greater demand for the currency and pushing its basis up (Iida, Kimura, and Sudo 2018). Therefore, as the yield curve

option works exactly the other way round. However, the prices of the call and the put are not necessarily the same, as there may be heavier betting for a rise in the asset than for a fall, or the other way round. Hence, the price difference can measure how asymmetric the market is in expecting a rise and a fall in the asset. See Wong and Fong (2018) for a more detailed discussion.

is essentially a function of monetary policy, term spread differential, which reflects the monetary policy divergence between two countries, can affect funding pressure in the swap market (Borio et al. 2016).

- *Credit Spread.* Last, but not least, counterparty credit risk is often cited as a prominent reason for the emergence and persistence of cross-currency bases in crisis periods (Baba and Packer 2009a; Coffey, Hrung, and Sarkar 2009; Ivashina, Scharfstein, and Stein 2015; Wong and Zhang 2018). The credit spread of the sovereign and corporate USD bonds of the economy (over U.S. Treasury securities) is used to account for the credit risk of the non-U.S. borrowers in the region.[14]

4. Model Specification and Data

In light of the potential driving forces identified above, our baseline regression model is specified as follows:

$$\begin{aligned} y_{it} = {} & \alpha_i + \beta_1 DollarG_t + \beta_2 DollarI_{it} + \beta_3 VOL_{it} + \beta_4 RiskRev_{it} \\ & + \beta_5 BASprd_{it} + \beta_6 BASprd3M_{it} + \beta_7 VIX_t \\ & + \beta_8 IntDiff_{it} + \beta_9 TermSprd_{it} + \beta_{10} CreditSprd_{it}, \end{aligned}$$

where

y_{it}	denotes the dollar funding stress for economy i as represented by the three-month FX swap or five-year CCBS basis of currency i vis-à-vis the U.S. dollar;
α_i	is the fixed effect of currency i;
$DollarG_t$	stands for the U.S. trade-weighted broad dollar index compiled by the Federal Reserve Board;
$DollarI_{it}$	is the residual obtained by regressing the exchange rate of currency i vis-à-vis the U.S. dollar on $DollarG_t$;

[14] We assume that the difference between the true credit risk and the credit risk as implied by credit spread, if any, is largely stable (due, for example, to stable investor preferences towards taking the credit risk of holding the bonds) such that the change in credit spread is a reasonable approximation of the change in the true credit risk premium.

VOL_{it}	represents the three-month 25-delta FX call option implied volatility of the exchange rate of currency i vis-à-vis the U.S. dollar;
$RiskRev_{it}$	denotes the three-month 25-delta FX option risk reversal of the exchange rate of currency i vis-à-vis the U.S. dollar;
$BASprd_{it}$	represents the bid-ask spread of the spot exchange rate of currency i vis-à-vis the U.S. dollar;
$BASprd3M_{it}$	denotes the bid-ask spread of the three-month forward exchange rate of currency i vis-à-vis the U.S. dollar;
VIX_t	is the 30-day forward-looking Volatility Index compiled by the Chicago Board Options Exchange;
$IntDiff_{it}$	represents the spread of the 10-year government bond yield of currency i over the 10-year U.S. Treasury bond yield;
$TermSprd_{it}$	measures the 10-year over 2-year spread differential between currency i government bond and U.S. Treasury markets; and
$CreditSprd_{it}$	represents the JP Morgan global aggregate bond credit spread index, which measures the spread of U.S.-dollar denominated sovereign and corporate bond yields of economy i over U.S. treasury yields.

All the variables take the form of their first difference. For simplicity, the three-month and five-year funding markets are chosen to represent the short- and long-term markets, respectively. All data are daily, covering the period from January 2007 to March 2021. There are 11 EMEAP economies, but data availability allows us to study only 8 of them, namely, Australia, Hong Kong, Japan, Korea, Malaysia, New Zealand, Singapore, and Thailand. The sources and statistical characteristics of the data are summarized in Appendix A.

Before estimating the model, we test the data for multicollinearity between the independent variables, which could potentially compromise the efficiency of the estimation. Figure 3 shows the correlation matrix of the independent variables. The correlation coefficient between *BASprd* and *BASprd3M* is 0.73, which indicates a very high positive correlation, though this should not be surprising (Krohn and Sushko 2020). In view of this, we need to drop one of

Figure 3. Correlation Matrix and Variance Inflation Factors of Explanatory Variables

	DollarG	DollarI	VOL	RiskRev	BASprd	BASprd3M	VIX	IntDiff	TermSprd	CreditSprd
TermSprd										0.2
IntDiff									0.54	0.41
VIX								0.28	0.1	0.22
BASprd3M							−0.02	−0.01	−0.01	−0.01
BASprd						0.73	−0.02	0.01	0	0
RiskRev					0.04	0.02	0.06	0	0.04	0.07
VOL				0.58	0.01	−0.01	0.18	0.04	0.05	0.11
DollarI			0.22	0.32	−0.01	−0.02	0.18	−0.01	0.03	0.04
DollarG		0.13	0.25	0.17	0	0	0.22	0.08	0.09	0.14
VIF*	1.12	1.16	1.62	1.63	-	1.00	1.21	1.73	1.44	1.23

*The variance inflation factor (VIF) is estimated after *BASprd* is removed.

them. We remove *BASprd* given the intuition that dollar funding in the cross-currency swap market is probably associated more with the liquidity in the forward market than in the spot market, but it does not really matter which one we retain given such a high correlation. The correlation coefficients of 0.58 between *VOL* and *RiskRev* and 0.54 between *IntDiff* and *TermSprd* are less than desired but acceptable in view of their variance inflation factors (VIFs).[15] The bottom

[15]The VIF is a measure of how much the variance (i.e., the standard error squared) of the estimated coefficient is inflated due to the existence of correlation among the independent variables in the regression. Specifically, the VIF for the *jth* independent variable is the reciprocal of $(1 - R_j^2)$, where R_j^2 is the R^2 value obtained by regressing the *jth* independent variable on the remaining independent variables. A VIF of one means that there is no correlation between

row in the figure shows that the VIF, a test of multicollinearity, for each remaining independent variable is way below five.

5. Empirical Results

To examine the effect of the potential candidates on dollar funding stress, we first estimate their normal market relationship in both the short- and long-term funding markets by regular linear regressions. We then move on to assess their distressed market relationship, employing the technique of quantile regression.

The estimates of the linear regressions, which are essentially least-squares based, represent the relationships between the FX swap or CCBS basis and the various driving forces under normal market conditions. Each of them is the average, or the conditional mean to be exact, relationship over a long period of time, more than 14 years in the present study. However, the relationship of interest to policymakers, e.g., those relationships described in Section 3, can possibly be buried in the data covering protracted and uneventful periods, in which non-U.S. financial institutions generally experience little dollar funding pressure. As a result, there should be little surprise that some of these estimates turn out to be insignificant or sometimes even carry the wrong sign. As we shall see, it happens to this study, just as it happens to many previous studies (e.g., Avdjiev et al. 2019; Barajas et al. 2020; Cerutti, Obstfeld, and Zhou 2021).

The distinct advantage of quantile regression is that it can enable us to evaluate the relationship between the dependent and independent variables across different quantiles of the conditional distribution of the dependent variable, which can be taken to represent different market conditions. Hence, this technique makes it possible to estimate the response of the basis to any potential factor under extreme scenarios, thereby helping uncover the relationship that is relevant and more important for policymaking. Appendix B explains why and how quantile regression can do it while regular linear regression cannot.

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the *jth* independent variable and the remaining independent variables, since the variance of b_j is not inflated at all. As a rule of thumb, a VIF greater than five indicates a problem of multicollinearity (Craney and Surles 2007).

5.1 Relationship in Normal Markets

Tables 1 and 2 present six sets of results for the short- and long-term dollar funding stress, respectively, under normal market conditions. In each of the tables, the second column lists the expected signs for the variables for ease of reference. The next six columns present the estimates obtained from (i) simple pooled regression; (ii) simple pooled regression with a lagged term of the dependent variable for correcting the first-order serial correlation; (iii) panel regression with currency fixed effects and a lagged term of the dependent variable for correcting the first-order serial correlation; (iv) panel regression with currency random effects and a lagged term of the dependent variable for correcting the first-order serial correlation; (v) pooled regression with the Newey-West (1987) robust covariance matric estimator to obtain the heteroskedasticity and autocorrelation corrected (HAC) standard errors; and (vi) pooled regression with the Driscoll-Kraay (1998) method to correct both cross-sectional and serial correlation to obtain the spatial correlation consistent (SCC) standard errors.

When the simple pooled regression model is estimated, diagnostic tests suggest the presence of potential serial correlation and cross-sectional correlation problems in both the short-term and long-term dollar funding stress equations. We thus reestimate the pooled model, and the panel models, with a lagged term. The fixed-effects model assumes that currency-specific effects are correlated with the independent variables (i.e., a group-specific fixed quantity), while the random effects model assumes currency-specific effects are uncorrelated (i.e., a random sample from the population). However, we find that both the fixed effects and random effects are insignificant at the 90 percent confidence level, suggesting that a simple pooled model is perhaps a better choice.[16] Indeed, as can be seen, there is practically no difference in the estimates between the models with and without currency-specific effects. When more sophisticated techniques are employed to correct for heteroskedasticity, and higher-order and cross-sectional autocorrelation, the results are of similar flavor, with some variables losing their statistical significance to different extents.

[16]The pooled regression model does not consider heterogeneity across groups or time.

Table 1. Short-Term Dollar Funding Stress: Currency-Specific Effects and Pooled Panel Data Regressions, January 2007–March 2021

	Expected Sign	Pooled	Pooled	Fixed	Random	HAC	SCC
(Intercept)		0.070	0.092		0.092	0.070	0.070
		(0.222)	(0.211)		(0.211)	(0.129)	(0.042)
lag(FXSwap)			**–0.311*****	**–0.311*****	**–0.311*****		
			(0.006)	(0.006)	(0.006)		
DollarG	–	–0.197	0.391	0.391	0.391	–0.197	–0.197
		(0.676)	(0.643)	(0.643)	(0.643)	(1.945)	(1.633)
DollarI	–	**–3.636*****	**–3.599*****	**–3.601*****	**–3.599*****	**–3.636***	**–3.636*****
		(0.439)	(0.417)	(0.417)	(0.417)	(1.418)	(1.014)
VOL	–	**–4.340*****	**–5.390*****	**–5.389*****	**–5.390*****	–4.340	**–4.340****
		(0.647)	(0.615)	(0.615)	(0.615)	(2.465)	(1.613)
RiskRev	–	**5.064****	**3.569***	**3.570***	**3.569***	5.064	**5.064***
		(1.544)	(1.468)	(1.468)	(1.468)	(8.895)	(2.382)
BASprd3M	–	**0.065*****	**0.050*****	**0.050*****	**0.050*****	0.065	**0.065*****
		(0.012)	(0.011)	(0.011)	(0.011)	(0.035)	(0.009)
VIX	–	0.082	0.112	0.112	0.112	0.082	0.082
		(0.126)	(0.120)	(0.120)	(0.120)	(0.281)	(0.074)
IntDiff	+	4.409	6.064	6.072	6.064	4.409	4.409
		(4.494)	(4.271)	(4.272)	(4.271)	(9.174)	(2.444)

(*continued*)

Table 1. (Continued)

	Expected Sign	Pooled	Pooled	Fixed	Random	HAC	SCC
TermSprd	+	**13.768***	**13.351***	**13.327***	**13.351***	13.768	**13.768***
		(5.726)	(5.442)	(5.443)	(5.442)	(12.148)	(5.751)
CreditSprd	−	**0.135***	0.104	0.104	0.104	0.135	0.135
		(0.056)	(0.054)	(0.054)	(0.054)	(0.117)	(0.090)
R^2		0.006	0.103	0.103	0.103		
Adj. R^2		0.006	0.102	0.102	0.102		
Num. Obs.		28,957	28,956	28,956	28,956		
Adequacy Test		DW = 1.951; Pesaran CD Test: p-value < 0.001		F-test: p-value = 0.946	Breusch-Pagan LM Test: p-value = 0.151		

Note: The third and fourth columns present the results of the pooled regression model without and with the lagged dependent variable, respectively. A Durbin–Watson statistic of 1.951 (with a p-value of less than 0.001) indicates the presence of positive serial correlations. A Pesaran (2004) cross-sectional dependence test yielding a p-value of less than 0.001 rejects the null hypothesis that the residuals are not correlated across the currencies. The fifth and sixth columns present the results of the fixed-effects and random-effects regression models. An F-test yielding a p-value of 0.946 fails to reject the null hypothesis that the fixed effects are insignificant, while a Breusch-Pagan (1980) Lagrange multiplier test yielding a p-value of 0.151 cannot reject the null hypothesis that the variances of the random effects are zero at the 90 percent confidence level. In the seventh column the Newey-West (1987) robust covariance matrix estimator is used to correct for serial correlation to obtain the heteroskedasticity and autocorrelation corrected (HAC) standard errors. In the eighth column, the Driscoll-Kraay (1998) method is used to correct both cross-sectional and serial correlation to obtain the spatial correlation consistent (SCC) standard errors. ***, **, and * denote that the estimated coefficient is statistically significant at 0.1 percent, 1 percent, and 5 percent, respectively.

Table 2. Long-Term Dollar Funding Stress: Currency-Specific Effects and Pooled Panel Data Regressions, January 2007–March 2021

	Expected Sign	Pooled	Pooled	Fixed	Random	HAC	SCC
(Intercept)		–0.002	–0.002		–0.002	–0.002	**–0.002***
		(0.021)	(0.021)		(0.021)	(0.019)	(0.001)
lag(CCBS)			**–0.062*****	**–0.062*****	**–0.062*****		
			(0.006)	(0.006)	(0.006)		
DollarG	–	–0.031	–0.031	–0.031	–0.031	–0.031	–0.031
		(0.063)	(0.062)	(0.062)	(0.062)	(0.105)	(0.070)
DollarI	–	**–0.226*****	**–0.208*****	**–0.208*****	**–0.208*****	**–0.226***	**–0.226****
		(0.040)	(0.040)	(0.040)	(0.040)	(0.111)	(0.073)
VOL	–	**–1.240*****	**–1.216*****	**–1.216*****	**–1.216*****	**–1.240*****	**–1.240*****
		(0.060)	(0.060)	(0.060)	(0.060)	(0.277)	(0.299)
RiskRev	–	**–0.867*****	**–0.904*****	**–0.904*****	**–0.904*****	–0.867	**–0.867*****
		(0.143)	(0.143)	(0.143)	(0.143)	(0.666)	(0.143)
BASprd3M	–	–0.002	**–0.002***	**–0.002***	**–0.002***	–0.002	**–0.002***
		(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)
VIX	–	**0.052*****	**0.053*****	**0.053*****	**0.053*****	**0.052***	0.052
		(0.012)	(0.012)	(0.012)	(0.012)	(0.022)	(0.029)
IntDiff	+	**–2.709*****	**–2.655*****	**–2.655*****	**–2.655*****	**–2.709*****	**–2.709***
		(0.405)	(0.404)	(0.404)	(0.404)	(0.783)	(1.107)

(*continued*)

Table 2. (Continued)

	Expected Sign	Pooled	Pooled	Fixed	Random	HAC	SCC
TermSprd	+	**1.785*****	**1.739*****	**1.739*****	**1.739*****	1.785	**1.785****
		(0.515)	(0.514)	(0.514)	(0.514)	(1.078)	(0.569)
CreditSprd	−	0.002	0.002	0.002	0.002	0.002	0.002
		(0.005)	(0.005)	(0.005)	(0.005)	(0.009)	(0.002)
R^2		0.037	0.041	0.041	0.041		
Adj. R^2		0.037	0.041	0.041	0.041		
Num. Obs.		29,111	29,110	29,110	29,110		
Adequacy Test		DW = 1.962; Pesaran CD Test: p-value < 0.001		F-test: p-value = 1.000	Breusch-Pagan LM Test: p-value = 0.046		

Note: The third and fourth columns present the results of the pooled regression model without and with the lagged dependent variable, respectively. A Durbin–Watson statistic of 1.951 (with a p-value of less than 0.001) indicates the presence of positive serial correlations. A Pesaran (2004) cross-sectional dependence test yielding a p-value of less than 0.001 rejects the null hypothesis that the residuals are not correlated across the currencies. The fifth and sixth columns present the results of the fixed-effects and random-effects regression models. An F-test yielding a p-value of 1 fails to reject the null hypothesis that the fixed effects are insignificant, while a Breusch-Pagan (1980) Lagrange multiplier test yielding a p-value of 0.046 cannot reject the null hypothesis that the variances of the random effects are zero at the 90 percent confidence level. In the seventh column the Newey-West (1987) robust covariance matrix estimator is used to correct for serial correlation to obtain the heteroskedasticity and autocorrelation corrected (HAC) standard errors. In the eighth column, the Driscoll-Kraay (1998) method is used to correct both cross-sectional and serial correlation to obtain the spatial correlation consistent (SCC) standard errors. ***, **, and * denote that the estimated coefficient is statistically significant at 0.1 percent, 1 percent, and 5 percent, respectively.

Looking at the overall picture, somewhat surprising to us is the coefficient of *DollarG*, which is found to be insignificant for both short- and long-term stress across different models and estimation techniques. On the contrary, the coefficient of *DollarI*, which measures dollar strength vis-à-vis the currency concerned that is not attributable to global dollar strength, turns out to be significant and carries a negative sign as expected in both the short- and long-term stress equations. This suggests that it is idiosyncratic, rather than global, dollar strength that causes dollar funding stress to the economy, a result that is at odds with that of Avdjiev et al. (2019). Nonetheless, it seems to make more sense than otherwise, given that dollar funding stress is largely an adversity suffered by non-U.S. financial institutions. From their perspective, when the U.S. dollar is weak against other major currencies, these borrowers are still likely to find it more difficult and costly to obtain dollar funding if their own currency is even weaker. The reason is that a larger amount of their own currency would be required as collateral for obtaining the same amount of dollar funding. We find that the risks pertaining to the stability of dollar strength vis-à-vis individual currencies are also important, as evidenced by the highly significant and negative coefficient of *VOL* in both the short- and long-term stress equations. This suggests that dollar funding stress in general tends to be associated with a volatile exchange rate. *RiskRev* is found to affect short-term stress positively and affect long-term stress negatively, though the impact is insignificant when it is estimated under HAC.

Turning to the variables other than those related to dollar strength, the effect of FX market liquidity is found to be positive on short-term dollar funding stress but insignificant under HAC. There is some negative, but very mild, impact on long-term dollar funding stress. General financial market volatility as proxied by *VIX* is also found to have little effect on short-term stress; it positively affects long-term stress, but the impact becomes much less significant under HAC and insignificant under SCC. Long-term interest differential as represented by *IntDiff* supposedly has a positive influence on dollar funding stress but is found to have no impact on short-term stress. Like Avdjiev et al. (2019), we find that it has a negative influence on long-term stress. *TermSprd*, which denotes the relative stance of monetary policy of the economy vis-à-vis the United States, is found to have a significant positive impact on both short- and long-term stress as expected. Finally, *CreditSprd* is found to have little influence on both.

For robustness and comparison, we present the results of the estimation of the short-term impact employing one-month and six-month FX swap bases and those of the long-term impact using one-year and three-year CCBS bases in Appendix C. Broadly speaking, they are highly consistent with those presented in the above. The major difference is that the magnitude of the coefficient is generally larger at the shorter end of the funding market, which is not surprising given the larger fluctuation of the data.

5.2 Relationship in Extreme Markets

While it is important to know the long-term driving forces behind what seems to be an intriguing global phenomenon, policymakers would probably find it more useful to understand the dynamics underpinning the phenomenon in times of market stress. This can be achieved with the aid of quantile regression.

Regardless of how the dependent variable responds to the independent variables under normal market conditions, it can behave quite differently in stressful times. As discussed, quantile regression can help us estimate the response of dollar funding stress to the driving forces under extreme market scenarios. In this study, the extremity of the scenarios is defined by dollar funding stress set progressively at the 25 percent, 20 percent, 10 percent, and 5 percent quantiles of its conditional distribution given that the greater the dollar funding stress, the more negative (or the less positive) is the FX swap or CCBS basis. The results of the quantile regressions for the three-month FX swap and five-year CCBS bases are presented in a progressive manner in Tables 3 and 4, respectively. As can be seen, compared with the least-squares estimates, the results of the quantile regressions apparently seem to be more clear-cut, especially when we move along the extremity scale. In the most extreme situation, no estimate which is found to be significant carries a wrong sign. These findings are highly robust across the basis spectrum, with the bases of other maturities showing consistent results (Appendix C). There are four points we wish to highlight.

Firstly, similar to what is found for the orderly market, idiosyncratic dollar strength is also an important driving force behind

Table 3. Short-Term Dollar Funding Stress: Quantile Regressions, January 2007–March 2021

	Expected Sign	Quantile			
		25%	**20%**	**10%**	**5%**
(Intercept)		**–4.067*****	**–5.599*****	**–12.001*****	**–22.113*****
		(0.070)	(0.089)	(0.211)	(0.485)
lag(FXSwap)		**–0.262*****	**–0.270*****	**–0.274*****	**–0.306****
		(0.001)	(0.002)	(0.005)	(0.005)
DollarG	–	**0.515****	0.392	**1.140***	1.140
		(0.166)	(0.222)	(0.571)	(1.346)
DollarI	–	**–0.619*****	**–0.684*****	**–1.395*****	**–3.011*****
		(0.137)	(0.110)	(0.326)	(0.786)
VOL	–	**–1.288*****	**–1.435*****	**–2.628*****	**–4.266*****
		(0.189)	(0.213)	(0.538)	(1.066)
RiskRev	–	–0.174	–0.422	–1.471	–3.754
		(0.514)	(0.639)	(1.477)	(3.232)
BASprd3M	–	**0.023*****	**0.024*****	**0.022***	0.026
		(0.001)	(0.003)	(0.010)	(0.020)
VIX	–	**0.073***	**0.089***	0.085	0.430
		(0.037)	(0.039)	(0.101)	(0.225)
IntDiff	+	**5.811*****	**6.756*****	**10.313****	**22.794****
		(1.207)	(1.518)	(3.600)	(8.509)
TermSprd	+	**–3.264***	–2.231	6.318	15.966
		(1.534)	(1.820)	(3.878)	(10.698)
CreditSprd	–	**–0.077*****	**–0.113*****	**–0.177*****	**–0.359****
		(0.016)	(0.020)	(0.052)	(0.116)
Num. Obs.		28,956	28,956	28,956	28,956

Note: ***, **, and * denote the estimated coefficient is statistically significant at 0.1 percent, 1 percent, and 5 percent, respectively.

both short- and long-term funding stress in the turbulent market with the coefficient of *DollarI* being negative and significant at all the quantiles. This suggests that as the market becomes chaotic, a stronger dollar vis-à-vis the currency concerned inflicts more stress on the borrower in the region. On the other hand, *DollarG* has a positive and negative impact on short-term and long-term dollar funding stress, respectively, as turbulence picks up initially. However, as we move towards the most extreme market, the impact vanishes in statistical significance in both cases, suggesting that global dollar

Table 4. Long-Term Dollar Funding Stress: Quantile Regressions, January 2007–March 2021

	Expected Sign	Quantile			
		25%	**20%**	**10%**	**5%**
(Intercept)		**–0.468*****	**–0.767*****	**–1.982*****	**–3.663*****
		(0.011)	(0.019)	(0.035)	(0.084)
lag(CCBS)		**–0.05*****	**–0.064*****	**–0.069*****	**–0.067****
		(0.002)	(0.004)	(0.007)	(0.020)
DollarG	–	**–0.061***	–0.056	–0.136	–0.361
		(0.027)	(0.053)	(0.086)	(0.227)
DollarI	–	**–0.060*****	**–0.061***	**–0.197*****	**–0.315****
		(0.016)	(0.029)	(0.059)	(0.112)
VOL	–	**–0.338*****	**–0.464*****	**–0.800*****	**–1.043*****
		(0.025)	(0.030)	(0.099)	(0.196)
RiskRev	–	**–0.268*****	**–0.239*****	**–0.515***	–0.992
		(0.079)	(0.072)	(0.253)	(0.522)
BASprd3M	–	0.000	0.000	–0.002	–0.002
		(0.000)	(0.001)	(0.002)	(0.002)
VIX	–	**0.017*****	**0.023****	**0.039***	0.064
		(0.005)	(0.009)	(0.017)	(0.040)
IntDiff	+	–0.145	–0.263	–1.161	–2.153
		(0.185)	(0.334)	(0.593)	(1.447)
TermSprd	+	0.106	0.148	1.278	3.384
		(0.226)	(0.440)	(0.711)	(1.849)
CreditSprd	–	**–0.005***	**–0.010****	**–0.020*****	**–0.033***
		(0.002)	(0.004)	(0.004)	(0.016)
Num. Obs.		29,110	29,110	29,110	29,110

Note: ***, **, and * denote the estimated coefficient is statistically significant at 0.1 percent, 1 percent, and 5 percent, respectively.

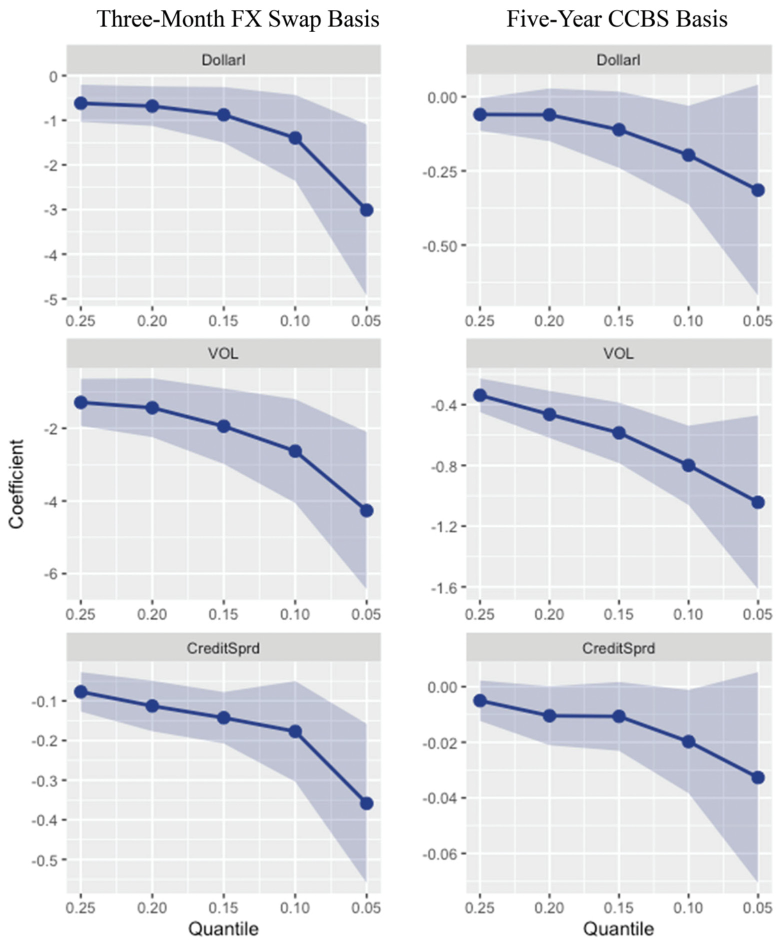
strength is irrelevant for the determination of dollar funding stress in crisis times as well as in normal markets.

Second, the volatility of dollar strength vis-à-vis individual currencies continues to play a critical role in determining both the FX swap and CCBS bases under extreme scenarios, with a consistently negative quantile estimate found for both short- and long-term stress. Exchange rate expectations play a much smaller role in stressful situations compared with normal market times. *RiskRev*, which can be interpreted as the expected dollar strength vis-à-vis the local currency, is found to have no impact on short-term stress. It maintains its impact on long-term stress initially as we move from the simple pooled regression to the quantile regressions, but the impact also disappears when we reach the lowest quantile in the estimation.

Third, the positive effect of *BASprd3M* on short-term stress found in the normal market lingers into the beginning of a turbulent market, but its statistical significance diminishes gradually towards the lowest quantile; it has no impact on long-term stress. Similarly, the coefficient of *VIX* is found to be positive amid increasing turbulence in both the short- and long-term equations but also becomes statistically insignificant at the lowest quantile. These findings suggest that FX market liquidity and general financial market volatility do not contribute to dollar funding stress, at least not under the most extreme scenario. Interestingly, *IntDiff,* which is found to have no impact on short-term stress in the orderly market, now shows up with a significant and increasing impact alongside the degree of market extremity. It has little impact on long-term stress, however, under extreme scenarios. On the contrary, *TermSprd*, which affects both the FX swap and CCBS bases significantly in the normal market, is found to have little influence over both short- and long-term funding stress, meaning that relative monetary conditions are only an important driver in the long run but not at critical moments. Most interesting to us is *CreditSprd*, a variable that is found to have no effect on short- or long-term stress at all during normal times, shows up as an important factor affecting dollar funding stress in both the short- and long-term markets as market conditions deteriorate. This means counterparty risk is an important element from the perspective of the dollar lending party, as reflected by the steeper compensation it demands from the borrower in turbulent times as compared with what would normally be required in a quiet market.

Finally, it is worth noting that the response of the variables that are found to be significant tends to intensify as turbulence gathers momentum. For example, the coefficient of *VOL* becomes more negative as we move towards a lower quantile in the estimation, reflecting that the more volatile the currency, the larger is the impact on the stress for the economy. Figure 4 provides a graphical exposition of the results of the various quantiles for *DollarI*, *VOL,* and *CreditSprd* to illustrate visually the extent to which the response exacerbates as market conditions worsen.

Figure 4. Response Sensitivity at Various Quantiles



Note: The shaded area represents the 95 percent confidence interval.

6. Concluding Remarks

Overall, the results of our estimation suggest that macrofinancial variables tend to behave quite differently in terms of how they affect dollar funding stress for the Asia-Pacific economies, as compared with what is found by previous studies. To some extent, this may be attributed to the fact that most previous studies are centered on the most advanced economies, while the economies under study here are a much more diverse group. The results also highlight the importance of differentiating the responses of the stress between normal and extreme market circumstances for policymaking and market surveillance.

Some recent studies have identified global dollar strength as probably the single most important factor that drives dollar funding stress. However, we find that it plays little role in determining both short- and long-term stress faced by EMEAP dollar borrowers in normal markets. It adds to long-term borrowing stress when turbulence begins to pick up, but the effect also dissipates as adversity deepens. On the contrary, idiosyncratic dollar strength is a major source of dollar funding pressure, regardless of whether it is in the short- or long-term market and irrespective of market conditions. In addition, uncertainty about dollar strength against individual currencies is found to be important both in orderly markets and in times of crisis. Currency expectations also play a role in the long-term market during normal market times, but their impact fades gradually when turbulence intensifies. Dollar funding stress also depends critically on monetary policy divergence over the long haul but not during crisis times.

Our findings suggest that credit risk which does not affect dollar funding stress in normal markets is an important consideration for the dollar lender in extending credit in turbulent times. This means that under stressful scenarios, economies that suffer a sharper deterioration in the credit outlook for their government, banks, and corporations (due possibly to a larger public debt or heavy borrowing) are likely to experience tighter funding conditions.

These results lend support to the policy of the Federal Reserve on establishing USD swap lines with other central banks. It was timely that the Federal Reserve extended the arrangement to nine more central banks early in the health crisis.[17] It is well known that some of the economies concerned have very volatile currencies, and most of them were expected to suffer a severe fiscal setback at the onset of

[17]On March 20, 2020, the arrangement of swaps lines was extended to nine more central banks, comprising US$60 billion each with the Monetary Authority of Singapore, Reserve Bank of Australia, Banco Central do Brasil, Danmarks Nationalbank, Bank of Korea, and Banco de Mexico, and US$30 billion each with the Reserve Bank of New Zealand, Norges Bank, and Sveriges Riksbank (https://www.federalreserve.gov/monetarypolicy/bst_liquidityswaps.htm).

the pandemic, which could trigger significant credit risk reappraisal for both the sovereign and financial institutions. In broadening the coverage of the facility further in the future, the Federal Reserve may wish to give more consideration to economies where the currencies are more likely to come under pressure and credit conditions tend to be more fragile in turbulent markets.

The findings also provide food for thought for policymakers in the region. For example, instead of monitoring global dollar strength as suggested in the literature, they should perhaps focus more on their own currency movement, volatility, and the market expectations about it. If they are concerned with potential financial contagion from their neighbors, they may also wish to keep a close eye on those who have a larger public debt or heavier corporate borrowing, which could render these economies more susceptible to a major credit risk reappraisal in times of crisis.

Appendix A. Sources and Descriptive Statistics of the Data

Table A.1. Sources of the Data

Variable	Description	Source
FXSwap	Three-month FX swap basis of foreign currency versus U.S. dollar	Bloomberg, RBNZ
CCBS	Five-year CCBS of foreign currency versus U.S. dollar	Bloomberg
DollarG	Federal Reserve Board U.S. trade-weighted broad dollar index	FRB of St. Louis
DollarI	Residual from regressing *DollarG* on bilateral exchange rate	Authors' estimation
VOL	Three-month 25-delta FX call option-implied volatility	JP Morgan database
RiskRev	Three-month 25-delta FX option risk reversal	JP Morgan database
BASprd	Bid-ask spread of spot exchange rate	Bloomberg
BASprd3M	Bid-ask spread of three-month forward exchange rate	Bloomberg
VIX	CBOE Volatility Index	Bloomberg
IntDiff	Yield spread of 10-year foreign govt. over 10-year U.S. Treasury	Bloomberg
TermSprd	10-year over 2-year spread differential (foreign govt. over U.S. Treasury)	Bloomberg
CreditSprd	JP Morgan global aggregate bond credit spread index	JP Morgan database

Table A.2. Descriptive Statistics of the Data

	Min.	Median	Mean	Max.	S.D.	Num. Obs.
FXSwap						
AUD/USD	–130.35	9.25	10.84	241.21	15.04	3,716
HKD/USD	–83.37	–16.68	–17.05	57.36	14.49	3,716
JPY/USD	–256.51	–24.06	–27.48	71.32	21.06	3,716
KRW/USD	–1,761.30	–60.93	–97.50	1,215.67	137.80	3,716
MYR/USD	–753.62	–50.41	–58.31	494.56	73.49	3,715
NZD/USD	–54.43	14.94	17.67	162.50	16.19	3,715
SGD/USD	–271.74	0.42	2.80	301.83	17.68	3,715
THB/USD	–302.16	–13.83	56.19	1,266.14	210.72	3,715
CCBS						
AUD/USD	–50.00	22.63	20.82	48.00	9.56	3,717
HKD/USD	–63.00	–9.00	–8.81	20.50	12.34	3,716
JPY/USD	–102.50	–49.00	–48.86	34.00	25.19	3,717
KRW/USD	–324.00	–76.00	–92.02	5.50	51.59	3,716
MYR/USD	–240.00	–79.00	–85.57	–3.00	41.73	3,715
NZD/USD	–5.50	26.30	24.85	52.00	11.90	3,717
SGD/USD	–69.00	–18.86	–20.78	2.50	12.40	3,716
THB/USD	–205.00	–20.00	–31.31	6.00	34.82	3,717
DollarG						
All Currencies	85.47	97.55	101.84	126.52	10.83	3,717
DollarI						
USD/AUD	–10.89	–0.77	0.06	32.79	6.44	3,717
USD/HKD	–0.55	–0.16	0.00	0.89	0.39	3,717
USD/JPY	–16.85	–0.67	0.01	23.15	9.08	3,717
USD/KRW	–18.54	–0.37	0.03	45.72	8.85	3,716
USD/MYR	–7.14	–0.96	–0.01	11.27	3.54	3,716
USD/NZD	–12.97	–0.98	0.06	41.67	8.22	3,717
USD/SGD	–7.52	–1.02	0.03	12.36	4.71	3,717
USD/THB	–9.06	–0.22	0.04	9.06	4.40	3,717
VOL						
USD/AUD	6.26	12.09	12.76	38.81	4.70	2,716
USD/HKD	0.28	0.77	0.91	5.46	0.56	3,716
USD/JPY	4.43	9.44	9.58	24.47	2.72	3,716
USD/KRW	3.54	10.70	12.39	68.31	7.65	3,716
USD/MYR	2.78	8.36	8.67	20.27	3.40	3,716
USD/NZD	6.72	12.96	13.56	36.22	4.56	3,716
USD/SGD	2.90	6.09	6.57	17.89	2.38	3,716
USD/THB	3.80	6.80	7.51	14.86	2.38	3,716

(*continued*)

Table A.2. (Continued)

	Min.	Median	Mean	Max.	S.D.	Num. Obs.
RiskRev						
USD/AUD	0.11	1.63	1.90	8.25	1.24	3,716
USD/HKD	–1.30	–0.35	–0.31	2.13	0.42	3,716
USD/JPY	–10.07	–1.23	–1.47	1.50	1.58	3,716
USD/KRW	–0.63	1.96	2.55	27.00	2.54	3,716
USD/MYR	–0.85	1.38	1.38	5.61	1.00	3,716
USD/NZD	0.14	1.62	1.89	8.00	1.20	3,716
USD/SGD	–0.68	0.88	0.89	4.47	0.68	3,716
USD/THB	0.27	1.08	1.15	4.63	0.60	3,716
VIX						
All Currencies	9.14	17.23	20.02	82.69	9.66	3,715
BASprd						
USD/AUD	–77.66	2.35	3.94	151.14	7.44	3,717
USD/HKD	0.77	0.78	1.39	32.81	1.34	3,717
USD/JPY	0.76	1.77	2.62	56.51	3.15	3,717
USD/KRW	1.01	16.95	17.26	372.65	25.77	3,716
USD/MYR	–167.61	12.34	13.42	59.91	9.81	3,677
USD/NZD	–1.53	4.31	7.02	473.35	13.34	3,717
USD/SGD	1.22	4.29	5.93	321.64	8.21	3,717
USD/THB	–647.95	8.32	15.38	448.33	29.18	3,717
BASprd3M						
USD/AUD	–72.60	2.68	4.43	168.38	8.10	3,717
USD/HKD	0.13	1.39	1.90	36.66	1.96	3,717
USD/JPY	–1.57	1.39	2.31	60.78	3.73	3,717
USD/KRW	1.59	47.26	63.16	652.27	61.87	3,716
USD/MYR	0.58	12.96	13.72	324.52	12.54	3,715
USD/NZD	–1.07	5.13	7.99	477.36	13.83	3,717
USD/SGD	0.23	5.26	7.70	215.21	10.03	3,717
USD/THB	–548.91	16.54	25.60	451.12	31.25	3,716
IntDiff						
AUD/USD	–0.86	1.14	1.01	2.77	0.93	3,717
HKD/USD	–2.05	–0.59	–0.61	0.28	0.28	3,716
JPY/USD	–3.36	–1.98	–1.92	–0.50	0.64	3,717
KRW/USD	–0.65	0.72	0.78	2.93	0.81	3,716
MYR/USD	–1.77	1.43	1.22	2.82	0.79	3,715
NZD/USD	–0.67	1.62	1.30	3.13	0.97	3,717
SGD/USD	–2.36	–0.34	–0.42	0.78	0.55	3,673
THB/USD	–1.29	0.47	0.55	2.17	0.65	3,715

(*continued*)

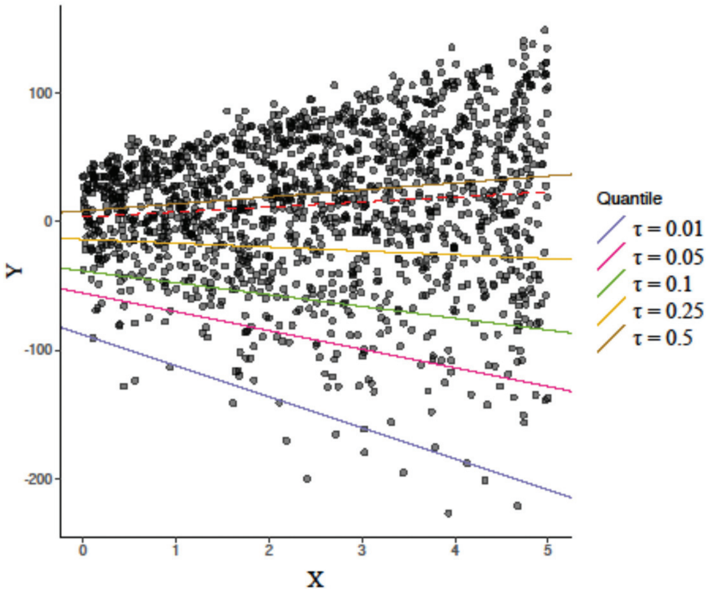
Table A.2. (Continued)

	Min.	**Median**	**Mean**	**Max.**	**S.D.**	**Num. Obs.**
			TermSprd			
AUD/USD	–2.51	–0.75	–0.72	0.52	0.73	3,717
HKD/USD	–1.70	–0.40	–0.38	0.52	0.32	3,422
JPY/USD	–2.02	–0.87	–0.82	1.12	0.65	3,717
KRW/USD	–2.20	–0.92	–0.82	1.06	0.65	3,716
MYR/USD	–2.07	–0.67	–0.66	0.45	0.70	3,715
NZD/USD	–2.17	–0.59	–0.58	0.78	0.66	3,717
SGD/USD	–1.15	–0.09	–0.15	1.20	0.33	3,673
THB/USD	–2.52	–0.36	–0.45	1.15	0.74	3,715
			CreditSprd			
AUD	27.96	144.79	164.21	470.00	69.20	3,716
HKD	63.75	246.37	253.45	673.31	81.69	3,716
JPY	50.94	124.59	139.45	347.59	49.28	3,716
KRW	49.71	131.03	169.99	706.27	114.14	3,716
MYR	66.00	159.70	175.21	495.97	64.73	3,716
NZD	48.06	112.91	137.25	408.43	72.67	3,716
SGD	59.32	136.94	151.04	466.11	60.64	3,716
THB	137.00	226.00	270.10	839.00	130.16	3,457

Appendix B. Quantile Regression

An ordinary least squares (OLS) regression estimates the mean response of the dependent variable to the independent variables based on the conditional mean function. Hence, this provides only a general or average view of the relationship between them. However, sometimes we are only interested in the relationship at certain points in the conditional distribution of the dependent variable, rather than at the mean. And in some cases, it is possible that a relationship does not exist at the mean at all but only at the tails of the conditional distribution. Quantile regression is an elegant technique of estimating the conditional median (or other quantiles) of the response variable. This technique is appealing due to its robustness to outliers and especially useful in the analysis of extreme events that lie in the high (or low) conditional quantiles for heavy tailed distributions.

Figure B.1. OLS and Quantile Regression Lines



Taking a similar formulation as the classical regression model, the quantile regression model for τth quantile can be written as

$$Q_\tau(y_i|x_1, x_2, \cdots, x_p) = \beta_0(\tau) + \beta_1(\tau)x_1 + \beta_2(\tau)x_2 + \cdots + \beta_p(\tau)x_p.$$

In contrast to being constants in the OLS regression, the beta coefficients are now functions with a dependency on the quantile level τ. The corresponding conditional quantile of y_i given x_p can be written as $Q_\tau(y_i|x_p)$ such that the quantile level τ is the probability of y_i equal to or less than its value estimated by the model, i.e., $Pr(y_i \leq Q_\tau(y_i|x_p)|x_p)$.

Figure B.1 presents an example of regression data for which both the mean and the variance of the response Y increase as the predictor X increases. The dashed line in the middle represents a simple OLS fit. The OLS regression models the conditional mean $E(Y|X)$ but does not capture the conditional variance $Var(Y|X)$. By fitting a series of quantile regression models for a grid of values of τ in the interval (0,1), we can describe the entire conditional distribution of the response. The solid lines in Figure B.1 show the fitted quantile regressions for the quantile levels at 1 percent, 5 percent, 10 percent, 25 percent, and 50 percent. In this particular example, the OLS regression line (the dashed line) conveys little information about the relationship between X and Y, as the fitted regression line has only a slight positive slope and does not describe the increasing dispersion of Y, while the quantile regression lines reveal interesting relationships. As can be seen, the decrease in response Y accelerates along the quantile scale as the predictor X increases, meaning that the relationship becomes more prominent as we move to the lower quantiles. This relationship, which apparently is negative, is not observable at the mean level.

Appendix C. Results of Cross-Currency Bases of Other Maturities

This appendix presents the results obtained by estimating the model using one-month and six-month FX swap bases, and one-year and three-year CCBS bases. Broadly speaking, they are highly consistent with those found for the three-month and five-year bases. As the fixed and random effects are insignificant, Table C.1 only shows the results of the simple pooled regression (with a lagged term of the dependent variable for correcting the first-order serial correlation) for comparison. As can be seen, like what we find for the three-month and five-year bases, *DollarI* and *VOL* are the only two variables that display a negative and significant coefficient across all maturities as expected. The estimates of all other variables can be significant with the right sign, insignificant, or significant with the wrong sign. As discussed in Section 5, this reflects the problem of estimating the mean relationship between the dependent and independent variables over a long period of time characterized mainly by a fairly calm market.

Tables C.2 and C.3 show the results estimated at various quantiles of the one- and six-month FX swap bases and one- and three-year CCBS bases, respectively. Similar to those for the three-month and five-year bases, the problem of ambiguity is gone as one moves towards the lowest quantile. No variable is found to be significant

Table C.1. FX Swap and CCBS Bases of Other Maturities: Pooled Regressions, January 2007–March 2021

	Expected Sign	1-Month	6-Month	1-Year	3-Year
(Intercept)		–0.018	0.002	–0.005	–0.002
		(0.598)	(0.105)	(0.024)	(0.020)
lag(FXSwap/ CCBS)		**–0.366*****	**–0.207*****	**–0.126*****	**–0.038*****
		(0.005)	(0.006)	(0.006)	(0.006)
DollarG	–	–1.226	**–0.864****	**0.263*****	0.040
		(1.815)	(0.317)	(0.072)	(0.060)
DollarI	–	**–11.812*****	**–1.108*****	**–0.243*****	**–0.267*****
		(1.163)	(0.207)	(0.046)	(0.038)
VOL	–	**–12.154*****	**–2.515*****	**–2.116*****	**–1.402*****
		(1.717)	(0.298)	(0.069)	(0.057)
RiskRev	–	**23.635*****	–1.306	**–2.394*****	**–1.078*****
		(4.133)	(0.730)	(0.165)	(0.140)
BASprd3M	–	**0.131*****	0.003	–0.002	–0.001
		(0.031)	(0.006)	(0.001)	(0.001)
VIX	–	**0.867****	0.055	**0.070*****	**0.063*****
		(0.332)	(0.059)	(0.013)	(0.011)
IntDiff	+	7.339	2.829	**–3.229*****	**–3.123*****
		(11.734)	(1.983)	(0.468)	(0.388)
TermSprd	+	3.234	0.564	**3.523*****	**2.180*****
		(14.946)	(2.278)	(0.595)	(0.498)
CreditSprd	–	0.220	0.015	0.008	–0.003
		(0.149)	(0.025)	(0.006)	(0.005)
R^2		0.142	0.051	0.104	0.054
Adj. R^2		0.141	0.050	0.104	0.054
Num. Obs.		29,069	27,603	29,124	28,918

Note: ***, **, and * denote the estimated coefficient is statistically significant at 0.1 percent, 1 percent, and 5 percent, respectively.

with the wrong sign in the most extreme scenario. Again, *DollarI* and *VOL* display consistently their undesirable impact on both short- and long-term dollar funding stress in times of market turmoil as expected, while *CreditSprd,* which is found to have no influence at all in normal markets, emerges as a key determinant in crisis times.

Table C.2. One-Month and Six-Month FX Swap Bases: Quantile Regressions, January 2007–March 2021

		Quantile				Quantile			
		25%	**20%**	**10%**	**5%**	**25%**	**20%**	**10%**	**5%**
	Expected Sign	*1-Month FX Swap Basis*				*6-Month FX Swap Basis*			
(Intercept)		**–9.699*****	**–13.687*****	**–29.930*****	**–56.621*****	**–1.975*****	**–2.717*****	**–5.655*****	**–10.080*****
		(0.181)	(0.239)	(0.552)	(1.323)	(0.034)	(0.043)	(0.091)	(0.229)
lag(FXSwap)		**–0.312*****	**–0.321*****	**–0.349*****	**–0.372*****	**–0.100*****	**–0.108*****	**–0.099*****	**–0.092*****
		(0.003)	(0.004)	(0.004)	(0.007)	(0.002)	(0.002)	(0.005)	(0.010)
DollarG	–	**2.095*****	**2.537*****	**3.204***	6.845	**–0.177****	–0.125	**–0.308***	–0.451
		(0.503)	(0.638)	(1.546)	(3.685)	(0.089)	(0.108)	(0.178)	(0.637)
DollarI	–	**–0.899****	**–1.074***	**–2.556*****	**–7.949*****	**–0.561*****	**–0.607*****	**–0.668*****	**–0.926****
		(0.331)	(0.436)	(0.675)	(2.141)	(0.058)	(0.067)	(0.125)	(0.360)
VOL	–	**–2.732*****	**–3.093*****	**–5.433*****	**–10.719*****	**–1.472*****	**–1.704*****	**–2.124*****	**–3.301*****
		(0.463)	(0.520)	(0.881)	(3.006)	(0.051)	(0.091)	(0.185)	(0.491)
RiskRev	–	1.746	0.410	2.667	5.788	**–0.474*****	**–0.871*****	**–1.458****	**–2.734****
		(1.262)	(1.685)	(2.697)	(7.953)	(0.154)	(0.187)	(0.588)	(1.160)
BASprd3M	–	**0.051*****	**0.055*****	0.040	0.076	**0.005*****	**0.002***	0.004	0.011
		(0.008)	(0.012)	(0.026)	(0.064)	(0.001)	(0.001)	(0.003)	(0.010)
VIX	–	0.144	0.140	0.181	0.339	–0.018	–0.014	0.019	0.124
		(0.085)	(0.116)	(0.283)	(0.629)	(0.016)	(0.019)	(0.020)	(0.087)
IntDiff	+	**14.317*****	**14.255*****	**23.792***	**49.455****	**6.171*****	**7.066*****	**7.519*****	**9.954****
		(3.061)	(4.240)	(9.752)	(18.718)	(0.547)	(0.676)	(1.410)	(4.167)
TermSprd	+	**–9.012***	–4.141	–7.296	8.771	**–5.798*****	**–6.004*****	**–5.057*****	–0.609
		(3.965)	(4.977)	(12.615)	(16.138)	(0.738)	(0.728)	(1.490)	(5.410)
CreditSprd	–	**–0.214*****	**–0.250*****	**–0.337****	**–0.647***	**–0.042*****	**–0.058*****	**–0.072*****	**–0.109****
		(0.043)	(0.055)	(0.122)	(0.302)	(0.006)	(0.009)	(0.016)	(0.051)
Num. Obs.		29,069	29,069	29,069	29,069	27,603	27,603	27,603	27,603

Note: ***, **, and * denote the estimated coefficient is statistically significant at 0.1 percent, 1 percent, and 5 percent, respectively.

Table C.3. One-Year and Three-Year CCBS Bases: Quantile Regressions, January 2007–March 2021

		Quantile				Quantile			
		25%	**20%**	**10%**	**5%**	**25%**	**20%**	**10%**	**5%**
	Expected Sign	*One-Year CCBS Basis*				*Three-Year CCBS Basis*			
(Intercept)		**–0.440*****	**–0.733*****	**–1.911*****	**–3.559*****	**–0.429*****	**–0.702*****	**–1.780*****	**–3.440*****
		(0.012)	(0.018)	(0.034)	(0.078)	(0.012)	(0.018)	(0.037)	(0.080)
lag(CCBS)		**–0.067*****	**–0.076*****	**–0.092*****	**–0.095*****	**–0.051*****	**–0.062*****	**–0.071*****	**–0.053*****
		(0.002)	(0.004)	(0.005)	(0.012)	(0.003)	(0.003)	(0.009)	(0.016)
DollarG	–	0.041	0.061	0.127	0.102	**–0.063***	–0.087	**–0.234***	–0.398
		(0.031)	(0.049)	(0.082)	(0.219)	(0.031)	(0.049)	(0.102)	(0.213)
DollarI	–	**–0.110*****	**–0.147*****	**–0.268*****	**–0.522*****	**–0.067*****	**–0.095****	**–0.236*****	**–0.467*****
		(0.018)	(0.032)	(0.036)	(0.129)	(0.019)	(0.031)	(0.068)	(0.080)
VOL	–	**–0.475*****	**–0.626*****	**–1.190*****	**–1.710*****	**–0.373*****	**–0.502*****	**–0.896*****	**–1.423*****
		(0.029)	(0.047)	(0.046)	(0.207)	(0.029)	(0.047)	(0.101)	(0.183)
RiskRev	–	**–0.290*****	**–0.419*****	**–0.936*****	–0.792	**–0.149***	–0.181	–0.450	–0.492
		(0.054)	(0.123)	(0.113)	(0.589)	(0.076)	(0.129)	(0.232)	(0.479)
BASprd3M	–	**–0.002*****	**–0.002****	**–0.002***	–0.003	**–0.001*****	–0.001	–0.002	0.000
		(0.000)	(0.001)	(0.001)	(0.003)	(0.000)	(0.001)	(0.002)	(0.003)
VIX	–	0.011	**0.023****	**0.051*****	0.075	0.008	0.015	0.035	0.052
		(0.006)	(0.009)	(0.013)	(0.041)	(0.005)	(0.008)	(0.020)	(0.043)
IntDiff	+	**–0.615*****	**–1.163*****	**–1.927*****	–2.089	–0.023	–0.077	–0.774	–1.660
		(0.167)	(0.259)	(0.491)	(1.353)	(0.179)	(0.290)	(0.669)	(1.449)
TermSprd	+	**0.773****	**1.323*****	**2.895*****	**3.708***	0.075	0.202	1.518	**4.196***
		(0.240)	(0.340)	(0.697)	(1.640)	(0.222)	(0.375)	(0.779)	(1.846)
CreditSprd	–	**–0.005***	**–0.009***	**–0.019*****	**–0.036***	**–0.016*****	**–0.020*****	**–0.036*****	**–0.057***
		(0.002)	(0.004)	(0.005)	(0.017)	(0.003)	(0.004)	(0.010)	(0.022)
Num. Obs.		29,124	29,124	29,124	29,124	28,918	28,918	28,918	28,918

Note: ***, **, and * denote the estimated coefficient is statistically significant at 0.1 percent, 1 percent, and 5 percent, respectively.

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