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US Monetary Policy and the Financial Channel of the Exchange Rate: Evidence from India

Shesadri Banerjee♦ and M. S. Mohanty♠#

Abstract

The effect of US monetary policy on EMEs is one of the fiercely debated issues in international finance. We contribute to this debate using micro- and macro-level analyses from India over the period 2004-2019. Using a dynamic panel estimation model of non-financial firms, we show that US monetary tightening adversely affects firms' net worth and reduces domestic credit relative to external credit. Using a sign-identified VAR model, we find that the contractionary US monetary policy leads to a significant downturn in the domestic credit and business cycles. The responses of firms and the impact on the domestic credit cycle suggest that the financial channel of the exchange rate is one of the conduits transmitting US monetary policy to India.

Keywords: US monetary policy, international transmission of monetary policy, dynamic panel estimation, sign-restricted VAR model, financial channel, Indian economy.

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1. Introduction

In the past decade, there has been a growing recognition of the fact that a high level of dollar debt in emerging market economies (EMEs) has made them more vulnerable to changes in US monetary policy. Under these conditions, a local currency depreciation against the dollar can lower output by causing a deterioration in the balance sheet conditions of firms exposed to unhedged dollar debt. The term "contractionary devaluation" became highly popular in the 2000s following the emergence of third-generation crisis models such as Chang and Velasco (1999); Aghion, Baccheta and Banerjee (2001); Cespedes, Chang and Velasco (2004) and Gertler, Gilchrist and Natalucci (2007). In these models, a firm's investment drops in response to devaluation given its reduced ability to support credit following a reduction in its net worth.[1]

A complementary view has argued that the exchange rate has significant effects on the supply of credit, offering a lender-side perspective to the contractionary devaluation hypothesis. For instance, Bruno and Shin (2015a and 2015b) show that local currency appreciation against the dollar influences the effective credit risks faced by the banks when they lend to borrowers that have currency mismatches in their balance sheets. This acts as a 'supply-push' factor for the banking sector flows to EMEs. Likewise, emphasizing the rising importance of the US dollar in the global financial system, Rey (2013) and Miranda-Agrippino and Rey (2015) show that US monetary policy has been a significant driver of the global financial cycle.[2] While issuing debt in domestic currency can reduce the vulnerability of the borrowing firm, it shifts the underlying exchange rate risk to the foreign lenders' balance sheet, affecting their credit supply (Carstens and Shin, 2019). In both micro-founded and the finance-based models, US monetary policy transmits to EMEs via the exchange rate and the balance sheet channels causing fluctuations in credit aggregates.

We build this paper on the aforesaid literature by examining the role of exchange rate-induced credit fluctuations in the transmission of US monetary policy to EMEs. Specifically, we combine micro- and macro-level evidence to explore whether there exists a financial channel of the exchange rate in the international transmission of monetary policy and how this channel might operate through credit aggregates. In doing so, we base our analysis on the Indian firm-level data. India provides an example of a typical EME that relies heavily on foreign currency debt to finance domestic investment while at the same time leaving a significant currency mismatch in its non-financial corporate sector.

We proceed in two stages. In the first stage, using dynamic panel models, we identify the balance sheet effect of the exchange rate by estimating the firm-level response of domestic vis-à-vis external borrowing as well as the change in firms' net worth to the change in US monetary policy and the nominal exchange rate. Our data set consists of the annual financial statements (2004 - 2019) of Indian non-financial firms reported by the Prowess IQ database, maintained and updated by the Centre for Monitoring Indian Economy (CMIE). India's restricted capital account regime allows only large, reputed non-financial firms to access the international capital market through what is known as the External Commercial Borrowing (ECB) channel. To construct a comparable and consistent group of firms with and without access to ECB, we narrow down our sample to the top 10 per cent of the firms by the size of their total liability.

In the second stage, using inferences from the firm-level analysis, we estimate a sign-restricted VAR model (2004:Q4 - 2018:Q4) to study the macroeconomic impact of US monetary policy. In the macro-level analysis, specifically, we exploit the identification scheme based on the evidence from the micro-level

[1] Some of the recent papers examining investment response to currency depreciation are Kalemli-Ozcan et al. (2016), Dao et al. (2017) and Avdjiev et al. (2019).

[2] See Kalemli-Ozcan et al. (2018), Bruno and Shin (2019) and Hofmann et al. (2019) for evidence on the impact of the exchange rate on banks' risk-taking behaviour and the supply of credit.

data. We impose a positive sign-restriction on the impulse response of the corporate bond spread in consequence of the tightening of US monetary policy and depreciation of the rupee/dollar exchange rate. Such sign-restriction is rationalized by the fact that the creditworthiness of the domestic firms declines with the depreciation of the exchange rate triggered by the US monetary tightening. We start with a baseline model which is fairly agnostic in nature and then examine the robustness of our results using alternative indicators of US monetary policy.

A key variable in our model is relative credit, which is defined as the ratio of domestic borrowing by non-financial firms (i.e., credit from local commercial banks) to external borrowing by these firms (i.e., direct borrowing from international markets). The basic intuition is that relative credit can be a major summary indicator of the demand- and supply-side factors affecting the two credit markets. As noted by Borio et al. (2011), in typical boom periods, cross-border credit tends to grow faster than domestic credit, as banks resort to the wholesale dollar market to finance new credit growth. In their analysis, expected currency appreciation plays a key role in amplifying the impact of looser US monetary policy on domestic credit. The process reverses itself with higher US interest rates inducing banks to unwind their short dollar positions, causing widespread credit slowdown in EMEs.

Our relative credit variable captures these dynamics well, reflecting the balance sheet conditions of firms. For instance, in economies that do not suffer from the currency mismatch problem, a tighter US monetary policy is likely to prompt the firms to substitute away from external borrowing to domestic borrowing. At the same time, the shock leads to a reallocation of capital away from EMEs as the relative return in US rises. Both demand and supply factors lead to increased domestic credit relative to external credit, helping firms to smooth out the impact of US monetary tightening and thereby strengthening the expansionary effect of currency depreciation through the trade channel. By contrast, in cases where firms carry substantial unhedged exchange rate positions, the relative credit variable moves in the opposite direction. Instead of compensating for an increased cost and reduced availability of external credit, domestic credit declines with contractionary implications for the economy.

Our empirical analyses have three key findings. First, controlling for firm-specific factors, the micro-level results suggest that a tighter US monetary policy has an adverse effect on the financing conditions of Indian non-financial firms. Rupee depreciation combined with higher US interest rates and unhedged foreign currency debt precipitate a contraction in relative credit. Second, our panel estimation results suggest a statistically significant negative relationship between changes in US monetary policy and changes in the firm's net worth, confirming the importance of a balance sheet effect of international monetary transmission in driving credit variables. Rupee depreciation magnifies liabilities that are valued in dollars and leads to a decline in the net worth of the borrowing firms. The coefficient of interaction between the change in US monetary policy, the rupee exchange rate and the foreign currency exposure of firms turns out to be statistically and economically significant, underscoring the vital role played by US monetary policy in Indian non-financial firms' balance sheet conditions and their access to credit. Finally, our macro-level analysis suggests that the domestic credit and business cycles go through a pronounced downswing nearly for six to eight quarters following the US monetary tightening.[3] Comparing the accumulated effect of shock, we find that a one per cent hike in the fed funds rate/shadow rate can depress domestic credit relative to external credit by 6.6 per cent and output by 0.76 per cent from their respective long-run levels. The contractionary impact of a rise in US longer-term interest rate turns out to be stronger than that of the short-term rate. Our results suggest the scope for policy intervention. To the

[3] While the contraction in the domestic credit and business cycles takes place following the shock, there could be a lag in the adjustment mechanism depending on the choice of US monetary policy indicator.

extent that the domestic monetary authority leans against the exchange rate, it is likely to slow down the rate of currency depreciation and credit contraction.

Our paper is related to several strands of literature on the international transmission of US monetary policy. These include macro-based studies that focus on the cross-border spillover of monetary policy (Fratzscher et al., 2013; Mohanty, 2014; McCauley et al., 2015b; Banerjee and Basu, 2016), as well as those investigating the role of specific channels such as the international credit channel (Cetorelli and Goldberg, 2012; Takats and Vela, 2014), the risk-taking channel (Morais et al., 2019) and the portfolio rebalancing channel (Burger et al., 2015). Parallel to these explorations, there are two strands of literature discussing the financial channels of the exchange rate, namely (i) models with agency costs and net worth in open economy settings and (ii) risk-taking channel of currency appreciation. The former is discussed in Gertler et al. (2007) which extends the closed economy financial accelerator model of Bernanke et al. (1989) to an open economy framework, while the latter channel is discussed in Bruno and Shin (2017) and several other papers dealing with currency mismatches (Chui, Kuruc and Turner, 2016; Banerjee, Hofmann and Mehrotra, 2020).

While some of the macro- and micro-level studies provide critical evidence on the operation of the exchange rate channel in EMEs, others remain silent about the underlying transmission mechanism. For instance, macro-level studies focus primarily on the optimal policy at the economy-wide level (e.g., third-generation crisis models). Identification is not empirically founded rather being based on assumptions about the structure of the economy and the practice of currency hedging. Micro-level studies, on the other hand, can address the identification issue more effectively, although they are unlikely to provide much guidance on the macroeconomic implications of the exchange rate shocks. In this paper, our objective is to bridge the gap between these two strands of literature. Using micro-based evidence, we try to identify the presence of the financial channel of the exchange rate and then complement it by exploring the cross-border monetary policy transmission from the macroeconomic perspective. We aim to contribute to this research gap of the literature with country-specific evidence from the Indian economy.

The rest of the paper is organized as follows. Section 2 explains the choice of the Indian economy as the testbed and describes the datasets under study. Section 3 discusses the micro-level evidence on US monetary policy transmission to Indian firms. Section 4 presents the macro-level evidence based on the sign-restricted VAR models. Section 5 concludes the paper.

2. Indian Economy: A Case for Analysis

It is well known that risks related to rapid increases in dollar debt issuance by emerging market non-financial corporate borrowers that are either unhedged or partially hedged against currency risks have risen sharply following the GFC (Schreger and Du, 2014; McCauley et al., 2015a; Chui, Kuruc and Turner, 2016). Under these conditions, the US monetary policy-induced exchange rate changes can lead to severe macroeconomic consequences for the economy. A large body of literature already exists pointing to the contractionary effects of currency depreciation in Latin America and central and eastern Europe where currency mismatches have historically remained high (Ranciere et al. 2010; Tobal, 2018). In contrast, there is little evidence to date about the importance of such a channel of transmission in the context of the Asian economies. Hence, empirical investigation of an economy from this region can provide useful insights into the implications of the financial channel of the exchange rate from the spatial perspective.

India constitutes a natural case study for our analysis for several reasons. First, in the past decade, India has witnessed a steep rise in currency mismatches. One recent official committee reported the magnitude of unhedged foreign currency debt in India being 3 to 4 times higher than that of the naturally hedged debt (Sahoo, 2015). Second, similarities in the structure of the economy with other economies in the region – such as the degree of underdevelopment of the corporate bond and FX hedging markets, presence of domestic credit market frictions and the dual structure of formal-informal finance - make India a representative case for our analysis. Third, rising currency mismatches has been identified as a major macroeconomic risk factor for the Indian economy, particularly in the aftermath of the GFC (Acharya et al., 2015; Patnaik et al., 2016). Given such currency risk exposures, the cross-border monetary transmission via the financial channel of the exchange rate can arguably be a significant driver of credit and output in the economy. In what follows, we first describe our datasets and then document a few stylized facts about the Indian economy.

2.1 Description of the Data

2.1.1 Non-financial Firm-level Data for Dynamic Panel Estimation

We rely on the CMIE Prowess IQ database which provides financial data annually for all Indian firms, both listed as well as unlisted, and has been used in several other research works for firm-level analysis (Bhue et al., 2015; Gopalan et al., 2016). We collate data for 39660 non-financial firms from this database and select firms that have reported their financial statements at least for two years during 2004 - 2019. Our sample period covers the longest possible time available in the database for the relevant data indicators.

While sorting the firms, we focus on a comparable and consistent group of firms with and without access to foreign currency borrowings. We apply a general rule for picking up the firms that are in the top 10 per cent of the sample in terms of their total liabilities.[4] Our sorting process of the firms using the "total liability" variable helps to circumvent the problem of sample selection bias as this indicator encompasses several aspects of firms' resource deployment in addition to the components of secured and unsecured loans and the current liabilities and provisions. Trimming down 90 per cent of firms from the dataset helps us to target the firms that represent the firm-level liability position better (87 per cent of the total liabilities of all firms) and are analytically relevant for the identification of the financial channel of the exchange rate. Our sorting process yields 3714 firms, of which 888 firms have borrowings in foreign currency. Overall, the proportion of the firms as the control group is three-fourth in our sample.

The firm-specific variables of our sample include total liabilities ($lib_{i,t}$), total borrowing ($brw_{i,t}$), external commercial borrowing ($ecb_{i,t}$), domestic borrowing $\left(dcb_{i,t}\right)$, total assets ($asset_{i,t}$), net worth ($nw_{i,t}$), total income ($income_{i,t}$), sales ($sales_{i,t}$), profit after tax ($pat_{i,t}$), export-to-sales ratio ($esr_{i,t}$) and the ratio of raw material import to input purchase ($inp\_rw_{i,t}$).

One limitation of our firm-level dataset is that it does not provide information on financial hedges such as foreign currency assets and currency derivative positions that could be used by the firm to hedge currency risk. Nevertheless, the dataset includes variables like export-to-sales ratio and the ratio of raw material imports to total raw material purchases to measure the degree of natural hedge. Besides, we define foreign currency borrowing ($fcbr_{i,t}$) as the ratio of the aggregate value of a firm's foreign currency credit (both long-term and short-term borrowings) to its total assets to measure the firm's exposure to currency risk. It represents the sum of both secured and unsecured foreign currency exposures of a firm and captures the extent of its currency mismatch. The summary statistics of firm-specific variables are presented in Table 1.

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[4] Using the firms with a-priori information regarding their external commercial borrowing can lead to selection bias. Hence, we apply a general rule for sorting firms based on their liabilities.

Table 1: Summary Statistics on Firm-specific Variables

Variables (in billions of Indian Rupee)	Mean	Median	Std. Dev	Obs.
lib	322.3	81.1	1400	40995
ecb	61	13.5	192.6	3947
dcb	229.4	37.2	741.8	3944
$asset$	322.4	81.1	1400	40981
nw	112.3	24.3	628.2	40995
$income$	238	59	1300	38815
$sales$	238.1	59.4	1300	36889
pat	9.8	1.6	99.3	39648
esr (in %)	47.9	0	5550.8	40739
inp_rw (in %)	18.6	0	661.9	40284
$fcbr$ (in %)	11.7	7.47	12.8	9265

Data on all firm-specific variables are passed through suitable transformation for the estimation. The firm's income is taken with logarithmic transformation, while the sales and profit net of tax are taken at their growth rates. We introduce the relative borrowing indicator $\left(drlb_{i,t}\right)$ as a measure of the firm's vulnerability to domestic and external credit market shocks. It is defined as the difference between the first order log-difference of domestic borrowing and external commercial borrowing, i.e., $drlb_{i,t} = \Delta ln\{dcb_{i,t}\} - \Delta ln\{ecb_{i,t}\}$. The domestic borrowing of the firm is computed by deducting the external commercial borrowing from its total borrowing. Change in the firm's net worth is calculated from the difference of net worth between two consecutive periods.

In addition to the firm-specific variables, we incorporate four macroeconomic variables at the annual frequency in the first difference for the panel estimation, namely, economic growth rate (Δyg_rate_t), the inflation rate ($\Delta infl_t$), the nominal effective exchange rate ($\Delta ln\{NER_t\}$) and the federal funds rate ($\Delta ff\_sh\_rate_t$). The first two variables are used as controls for the macroeconomic factors in the absence of year fixed-effects in the model, while the last two variables are employed to examine the financial channel of the exchange rate, particularly, the balance sheet effect emanating from US monetary policy. Our choice of macroeconomic variables is in line with Ioannidou, Ongena and Peydro (2008) who study the transmission of US monetary policy to the Bolivian economy using a panel of Bolivian non-financial firms.

2.1.2 Data for the Sign-restricted Vector Autoregression (SRVAR) Model Estimation

For the macro-level analysis, we select time series data on six macroeconomic and financial variables with quarterly frequency for the sample period 2004:Q4 to 2018:Q4. These include real output (Y_t), consumer price inflation (CPI_t), call money rate ($WCMR_t$), domestic credit relative to external commercial borrowing ($RLBP_t$), change in the nominal exchange rate (DEP_EX_t) and corporate bond spread (CBS_t). The data series of real output and relative credit indicator are seasonally adjusted and passed through

Christiano-Fitzgerald (2003) asymmetric band-pass filter to capture the movement over the business cycle.[5] Regarding US monetary policy, we consider three alternative indicators: the fed funds rate (US_FF_t), the 2-year US Treasury yield, and the US monetary policy surprise series similar to Gertler and Karadi (2015). We use Lombardi and Zhu (2018)'s estimates of the shadow fed funds rate for the periods when the effective fed funds rate was near zero. For both macro- and micro-level analyses, we primarily focus on the fed funds rate as our baseline case. However, for the robustness checking, we also consider the other two indicators. While the 2-year US Treasury yield (US_GS_t) is likely to be a more relevant indicator for investigating international transmission involving changes in the Federal Reserve's longer-term policy path (including forward guidance), the high-frequency monetary policy surprise (US_MPS_t) can shed light on the impact of unanticipated changes in the US monetary policy stance.[6]

2.2 Stylized Facts

We start with a few stylized facts about the macro-financial indicators of the Indian economy. The pre-GFC period was characterised by strong output and credit growth, with domestic and external borrowing rising above their trend levels by more than 14 per cent and 6 per cent, respectively. In particular, external commercial borrowing of non-financial firms registered nearly two-fold growth following the liberalization of capital account (Mohanty and Sundaresan, 2018; Pradhan and Hiremath, 2019). However, the expansion came to an end in the post-GFC period, with domestic credit decelerating significantly, while external borrowing continuing to expand at a steady rate during much of this period.[7] Such movements in credit indicators were accompanied by home currency appreciation (4.1 per cent) and depreciation (18.2 per cent) and cumulative US monetary easing and tightening of 2 and 2.1 percentage points, respectively, in the pre- and post-GFC periods.

Figure 1 shows that there exists an inverse relationship between the US fed funds rate and the relative credit indicator, with a statistically significant negative correlation (-0.45 at 1 per cent level of significance) for the full sample period. In particular, the turning points in credit seem to coincide with the turning points in US monetary policy. Besides, the graph suggests a negative association between relative credit and exchange rate depreciation, which is more remarkable in the post-GFC period than the sample as a whole.

To explore these interactions further we check cross-correlations of variables over the full sample and document the key features in Table 2.[8] Three stylized facts emerge. First, the cyclical component of the relative credit variable is negatively associated with the level and the change in the fed funds rate. Second, output positively co-moves with the change in relative credit but negatively correlates with the depreciation of the exchange rate. Finally, we observe that depreciation of the home currency and corporate bond spreads are positively correlated both at the level and changes over the previous year. These facts indicate that tighter US monetary policy causing a depreciation of the Rupee against the dollar can lead to a contraction in credit and output as predicted in Bernanke et al. (1999) and Cespedes et al. (2004).

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[5] Use of the level variable often masks various types of fluctuations ranging from the high-frequency movements to the long-term oscillations (Comin and Gertler, 2006), and makes it difficult to isolate the economically meaningful dynamic effects of the shock of our interest. We circumvent this problem by targeting the cyclical components of output and credit, which emerge from a specific periodicity of fluctuations and provide a better understanding of the shock-propagation.

[6] Further details on the firm-level and macro-financial data are provided in Appendix 1.

[7] For the discussion on the policy framework for the external commercial borrowing of the Indian firms, see Patnaik, Shah and Singh (2016) and for the trends and composition, see Figure 2 and 3 in Pradhan and Hiremath (2019).

[8] The time-series patterns of the relevant macroeconomic and financial indicators are presented in Figure A.1 in Appendix 1.

Figure 1: Ratio of Domestic to Foreign Currency Denominated Credit, Exchange Rate and US Monetary Policy Indicator

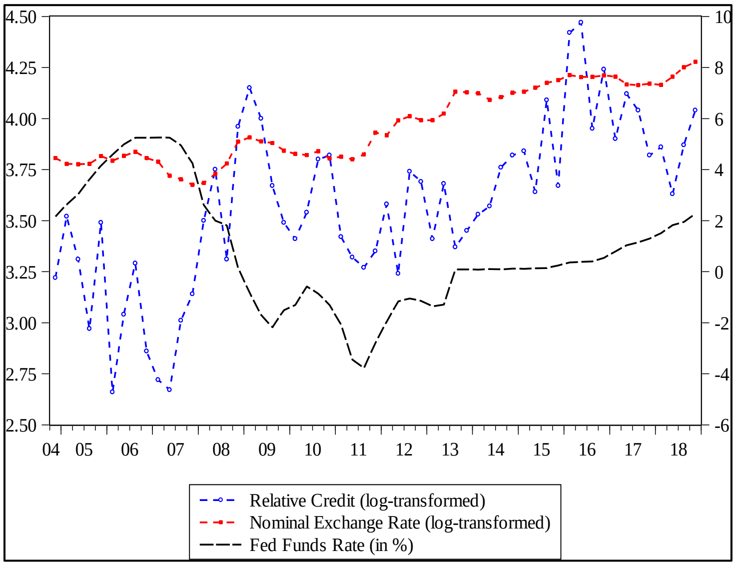


Table 2: Key Cross-correlations among Macro-financial Variables

Stylized Facts	Correlations	Values
Fact 1	$RLBP,\ US\_FF$	-0.31**
	$RLBP,\ \triangle US\_FF$	-0.27**
Fact 2	$Y,\ \triangle RLBP$	0.28**
	$Y,\ DEP\_EX$	-0.53***
Fact 3	DEP_EX, CBS	0.58***
	$\triangle DEP\_EX, \triangle CBS$	0.46***

Reinforcing the intuition obtained from the macro-financial indicators, the firm-level data suggests the possible presence of a balance sheet effect of the fed funds rate. The key observations are as follows. First, both domestic and foreign currency borrowings of the firms are positively correlated with net worth (0.62 and 0.61, respectively, at 1 per cent level of significance). Hence, changes in the firms' net worth can directly influence their borrowing pattern and the relative borrowing position. Second, there exists an inverse relationship between (i) the firms' net worth and the federal funds rate (-0.36 at 10 per cent level of significance), and (ii) the change in the firms' net worth and change in the federal funds rate (-0.6 at 1 per cent level of significance). Such cross-correlations, both at the level and the change in net worth and US policy rate indicate the potential existence of a financial channel for the cross-border transmission of US monetary policy.

Based on these stylized facts, in what follows we try to disentangle the financial channel of the exchange rate from other firm-specific and macroeconomic factors and evaluate the transmission of US monetary policy.

3. Micro-level Evidence on Financial Channel of the Exchange Rate

We estimate two sets of dynamic panel models. The motivation behind the choice of econometric models is as follows. First, we investigate if the relative borrowing variable of the firm responds to US monetary policy, subject to the firm's foreign currency risk exposure. If it does so, then, it is necessary to examine whether such an effect is linked to the firm's balance sheet conditions for which we estimate a separate model with the firm's net worth as the dependent variable. These dynamic panel estimation exercises are complementary to each other. While the first regression exercise identifies the transmission from the fed funds rate to the firm's credit variables through the exchange rate, the second confirms the potential channel of transmission. To this end, we use the method of two-step system GMM panel estimation as in Kim (2016). This procedure minimizes the potential bias in estimation for the endogeneity problem. In the following sub-sections, we discuss the model specifications and report the GMM system estimates of two separate estimation exercises along with the results of the Hansen test for validation of the instruments.[9]

3.1 Firm-level Credit Response to US Monetary Policy Transmission

3.1.1 Model Specification

As noted in the Introduction, the change in relative borrowing indicator is used to capture the substitution between the sources of funds. There are three major reasons why firms in EMEs may prefer foreign currency borrowing over domestic borrowing and why they may decide to leave the currency risk unhedged. First, the lack of monetary and fiscal credibility and supporting institutions for the development of domestic bond markets often compel the firms to borrow in foreign currency (Claessens et al. 2007). Second, government policies may provide implicitly or explicitly a bailout guarantee for the dollar debt that works as insurance against the exchange rate risk for the borrowing firms. Third, as noted by Korinek (2010) and Jeanne and Korinek (2010), firms may not fully internalise the systemic effects of foreign currency debt and the risk of financial amplification in their borrowing behaviour. Failure to take account of such externalities leads firms to undervalue exchange rate risks, causing excessive borrowing in foreign currency.

Subject to these frictions, when there is a change in the US monetary policy rate, the cost of raising capital from the international capital market alters, encouraging firms to reshuffle their credit portfolios between domestic and external sources of fund. However, when firms are saddled with unhedged foreign currency debt, not only is the substitution effect likely to be weak but it can be outweighed by the wealth effect arising from changes in the balance sheet position. That is, a dollar appreciation associated with tighter US monetary policy can precipitate sharp changes in the demand for and supply of credit for the firms exposed to large outstanding unhedged dollar debt. The relative borrowing variable is expected to reflect such changes.

To estimate the responsiveness of changes in relative borrowing variable of firms to the financial channel of the exchange rate, we use the following dynamic panel model:

$$drlb_{i,t} = \alpha_0 + \alpha_1 drlb_{i,t-1} + \sum_{m=1}^{M} \beta_m X_{i,t-s}^{F} + \sum_{p=1}^{P} \beta_p X_{t-s}^{D} + \sum_{q=1}^{Q} \gamma_q X_{i,t-s}^{Z} + \varepsilon_{i,t}^{rb} \qquad (1)$$

In the above equation, $|\alpha_1| < 1; i = 1, 2, \dots N; t = 1, 2, \dots T; s = 0, 1, \dots L; \varepsilon_{i,t}^{rb} = v_i^{rb} + \epsilon_{i,t}^{rb}$ where v_i^{rb} is the firm-specific fixed effect and $\epsilon_{i,t}^{rb}$ is the stochastic error term. $drlb_{i,t}$ denotes the change in relative borrowing of *i*^th^ firm at year *t*; $X_{i,t-s}^{F}$ denotes the set of firm-specific variables of *i*^th^ firm, X_{t-s}^{D} denotes the

[9] The Hansen J test is favoured over the Sargan test for assessing the validity of instruments because the Sargan test is prone to over reject the null of valid instruments in the presence of heteroscedastic and autocorrelated errors (Roodman, 2009).

controls for the domestic macroeconomic environment, and $X^{Z}_{i,t-s}$ denotes the vector of variables, which can be firm-specific and/or common to all firms. The vectors of firm-specific variables and the domestic macroeconomic controls include $X^{F}_{i,t-s}$: $ln(income_{i,t-1})$, $ln(pat_{i,t-1})$, $roa_{i,t}$, $gsales_{i,t}$, $esr_{i,t}$, $inp\_rw_{i,t}$; X^{D}_{t-s}: Δyg_rate_t, $\Delta infl_t$; respectively. In the estimation, we test the hypotheses: $\gamma_q \neq 0$. We use the model specification with alternative data indicators for $X^{Z}_{i,t-s}$ to examine the presence and robustness of $\gamma_q \neq 0$. Table 3 below presents the list of the alternative models used for the estimation.

Table 3: Responsiveness of Firm-level Relative Borrowing to US Monetary Policy

Dynamic Panel Models	Model Description
Model 1	$Baseline\ Model$ is Equation (1) without $X^{Z}_{i,t-s}$
Model 2	$Baseline\ Model$ with $X^{Z}_{i,t-s} = \Delta ln(NER_t)\ \ \forall\, i,j$
Model 3	$Baseline\ Model$ with $X^{Z}_{i,t-s} = \Delta ln(NER_t),\ \Delta ff\_sh\_rate_t, \forall\, i,j$
Model 4	$Baseline\ Model$ with $X^{Z}_{i,t-s} = \Delta ln(NER_t),\ \Delta ff\_sh\_rate_t, \{\Delta ff\_sh\_rate_t \text{ x } fcbr_{i,t-1}\}$ where; $\Delta ln(NER_t)$ and $\Delta ff\_sh\_rate_t$ *hold* $\forall\, i,j$ *and* $\{\Delta ff\_sh\_rate_t \text{ x } fcbr_{i,t-1}\}$ *holds* $\forall\, i,j$ *but* $i \neq j$
Model 5	$Baseline\ Model$ with $X^{Z}_{i,t-s} = \Delta ln(NER_t),\ \Delta ff\_sh\_rate_t, \{fcbr\ x\ ner\ x\ ff\}$ where; $\Delta ln(NER_t)$ *and* $\Delta ff\_sh\_rate_t$ *hold* $\forall\, i,j$ *and* $\{fcbr\ x\ ner\ x\ ff\} = \Delta ln(NER_t) \text{ x } \{\Delta ff\_sh\_rate_t\} \text{ x } fcbr_{i,t-1}$, *holds* $\forall\, i,j$ *but* $i \neq j$
Model 6	Model 5 is estimated for the post-GFC period (2009-2019)

We start with a baseline model i.e. Model 1 that regresses the change in relative borrowing on the firm-specific and domestic macroeconomic variables. In Model 2, we augment the baseline model with the nominal exchange rate in the vector of $X^{Z}_{i,t-s}$. The rationale is to examine if the exchange rate depreciation is contractionary and has a statistically significant influence on the firm's borrowing. In Model 3, we examine the effect of a change in US monetary policy by adding the same in $X^{Z}_{i,t-s}$ along with the nominal exchange rate. This underscores the marginal effect of the change in the fed funds rate in addition to the effect of the exchange rate on the relative credit.

In Model 4 and 5, we introduce interaction variables to identify the financial channels. Model 4 includes interaction between the firm-specific foreign currency borrowing to asset ratio and US monetary policy rate ($\Delta ff\_sh\_rate_t \text{ x } fcbr_{i,t-1}$). In Model 5, we replace the dual interaction variable with a triple interaction term ($fcbr\ x\ ner\ x\ ff$) that allows the interplay among firms' foreign currency exposures, the exchange rate and the fed funds rate. This interplay, essentially, pins down the possibility that the financial channel depends on the exchange rate. Finally, in Model 6, we do a sub-sample estimation of Model 5 for the post-GFC period to examine if there is any notable change in the responsiveness of relative borrowing to changes in US monetary policy. This provides a robustness check for our triple interaction variable.

3.1.2 Results

In Table 4, we report the results of estimation for different modelling strategies. The estimates of the baseline model show that the firm-level foreign currency exposure has a negative impact on domestic borrowing relative to external borrowing. Among the macroeconomic variables, the change in the inflation rate positively influences the change in relative borrowing. The estimates of the firm-specific variables like the growth rate of sales and export-to-sales ratio have statistically significant positive effects on the firm's relative borrowing. Sales growth is a proxy for the future growth prospects of the firm. The growth rate of profit gives a signal about the firm's performance and hence directly related to its creditworthiness. The export-to-sales ratio controls for the degree of natural hedge enjoyed by the firm - a positive coefficient implies an expansion in relative credit following an increase in the export revenue.

The results of Model 2 to Model 6 primarily suggest the presence of a financial channel of the exchange rate. The estimates of Model 2 shows that the exchange rate depreciation affects relative borrowing negatively (-0.0168). Likewise, Model 3 confirms the basic hypothesis that a US monetary tightening hurts the relative credit. The estimated coefficients of both variables are statistically significant at 5 per cent and 1 per cent level, respectively. In Model 4, while controlling for their independent effects, the double interaction term between US monetary policy and foreign currency borrowing to asset ratio turns out to be negative and statistically significant. As we replace this dual interaction variable with the triple interaction variable in Model 5, the estimated negative impact on credit remains in place and is statistically significant at 10 per cent level, both for the full sample and the post-GFC period (Model 6). These contractionary effects, as evident from the estimates of the interaction variables, imply that a currency depreciation induced by US monetary tightening has an amplifying effect on firms' credit conditions. Overall, our results have a broad resemblance with the studies which have shown adverse balance sheet effect of the exchange rate in EMEs (Carranza, Cayo and Galdon-Sanchez, 2003; Aguiar, 2005; and Gilchrist & Sim, 2007).

A key question is why do firms experience a reduction in domestic credit more than international credit following a rise in the US interest rate? This is possible when the financial channel of the exchange rate dominates, outweighing the substitution effect of US monetary tightening. For the firm, a substitution effect arises because the relative cost of borrowing moves in the favour of domestic credit. However, such a positive influence on the domestic credit cannot be sustained when the firm suffers substantial wealth losses from its unhedged foreign currency positions, leading to a deterioration in its creditworthiness. The fact that domestic credit decelerates suggests that local banks become more cautious in lending to these firms. Besides, as pointed by Bruno and Shin (2017), to the extent that domestic banks funded a significant part of their lending to the non-financial firms by accessing credit from the international banks, a dollar appreciation, by increasing the credit exposure of international banks, may reduce capital flows to the domestic banking system.

The strength of the wealth effect depends on the magnitude of unhedged currency risk in the balance sheet of firms. Even though we do not have comprehensive controls for the financial hedge, our results provide indirect support to the problem of currency mismatch in India. As noted earlier, the available evidence is, indeed, consistent with the fact that most Indian non-financial firms prefer to leave their foreign currency debt unhedged.[10]

[10] Using proprietary loan-level data for external commercial borrowing, Mohanty and Sundaresan (2018) report that only 23.3 per cent of Indian non-financial firms had expressed any desire to hedge currency and interest rate risks over the period 2000-2017.

Table 4: Effect of Change in US Monetary Policy on Firm's Borrowing Pattern

VARIABLES	(1) $drlb_{i,t}$	(2) $drlb_{i,t}$	(3) $drlb_{i,t}$	(4) $drlb_{i,t}$	(5) $drlb_{i,t}$	(6) $drlb_{i,t}$
$drlb_{i,t-1}$	-0.152**	-0.158***	0.0632	-0.0614	-0.00688	-0.00643
	(0.0598)	(0.0596)	(0.131)	(0.123)	(0.0879)	(0.0897)
$ln(income_{i,t-1})$	0.133	0.158	0.291**	0.0184	0.165	0.195
	(0.118)	(0.123)	(0.144)	(0.106)	(0.192)	(0.207)
$ln(pat_{i,t-1})$	-5.62e-06	-7.04e-06	9.14e-07	-1.99e-07	-3.46e-07	-2.61e-06
	(6.34e-06)	(6.53e-06)	(3.96e-06)	(3.97e-06)	(3.36e-06)	(4.25e-06)
$roa_{i,t}$	0.0393	0.0470	0.318	-0.172	-0.162	-0.150
	(0.175)	(0.174)	(0.281)	(0.246)	(0.187)	(0.195)
$fcbr_{i,t}$	-0.0550***	-0.0545***	-0.0554***	-0.0244**	-0.0141	-0.0161
	(0.0116)	(0.0113)	(0.0193)	(0.0108)	(0.00987)	(0.0107)
$gsales_{i,t}$	0.0244**	0.0268**	0.0462***	0.00977	0.0199	0.0208
	(0.0111)	(0.0111)	(0.0150)	(0.0151)	(0.0135)	(0.0139)
$esr_{i,t}$	0.00589***	0.00645***	0.00852***	0.00259	0.00252	0.00363
	(0.00214)	(0.00221)	(0.00323)	(0.00213)	(0.00257)	(0.00289)
$inp\_rw_{i,t}$	-4.06e-06	-4.58e-06	-1.50e-05***	-3.03e-06	-6.35e-06**	-6.78e-06***
	(2.96e-06)	(2.94e-06)	(5.01e-06)	(4.50e-06)	(2.50e-06)	(2.42e-06)
Δyg_rate_t	0.000962	-0.00993	0.0172	0.00417	0.00774	0.00502
	(0.0119)	(0.0129)	(0.0138)	(0.0111)	(0.0120)	(0.0121)
$\Delta infl_t$	0.0303**	0.0124	-0.00126	0.00391	0.0197	0.0317
	(0.0136)	(0.0153)	(0.0148)	(0.0134)	(0.0252)	(0.0293)
$\Delta ln(NER_t)$		-0.0168**	-0.0144**	-0.0182***	-0.00538	-0.00191
		(0.00667)	(0.00622)	(0.00596)	(0.00826)	(0.00962)
$\Delta ff\_sh\_rate_t$			-0.0824***	0.116	0.0286	0.0107
			(0.0293)	(0.0912)	(0.0620)	(0.0648)
$\{\Delta ff\_sh\_rate_t \text{ x } fcbr_{i,t-1}\}$				-0.0111*		
				(0.00604)		
$\{fcbr\ x\ ner\ x\ ff\}$					-0.000818*	-0.000792*
					(0.000423)	(0.000417)
Constant	-0.484	-0.673	-1.903	0.265	-1.345	-1.625
	(1.193)	(1.246)	(1.495)	(1.043)	(1.928)	(2.076)
AR (1)	-3.56***	-3.49***	-2.76***	-2.49***	-3.33***	-3.26***
AR (2)	-1.05	-1.17	0.22	-0.12	0.34	0.23
Hansen J-statistic	41.34	39.70	25.94	54.40	42.01	40.60
Observations	1,711	1,711	1,711	1,711	1,559	1,559
Number of id	476	476	476	476	462	462

*Note: Standard errors are in parentheses; *** p < 0.01, ** p < 0.05, * p < 0.1*

Our results are consistent with previous studies based on EME data. For instance, using firm-level data for 36 EMEs, Serena and Sousa (2017) find that, conditional on the amount of debt issued in foreign currency, an exchange rate depreciation can have a contractionary impact on a firm's investment spending.[11] The results are also in conformity with the findings of Barajas et al. (2017) and Niepmann and Schmidt-Eisenlohr (2017) which show that a US dollar appreciation is associated with a reduction in investment and a higher likelihood of default for the firms with a higher share of foreign currency loans.

3.2 Are the Impacts Related to the Balance Sheet Effect of US Monetary Policy?

To verify whether the impact of US monetary policy on firm-level credit is transmitted due to the balance sheet effect of the financial channel, we undertake a second round of micro-level investigation and examine whether firms' net worth also changes while their access to credit is affected. The econometric specification of dynamic panel estimation is presented below:

$$\Delta nw_{i,t} = \delta_0 + \delta_1 \Delta nw_{i,t-1} + \sum_{m=1}^{M} \eta_m X_{i,t-s}^{F} + \sum_{p=1}^{P} \eta_p X_{t-s}^{D} + \sum_{q=1}^{Q} \lambda_q X_{i,t-s}^{Z} + \varepsilon_{i,t}^{nw} \quad (2)$$

In equation (2), $|\delta_1| < 1; i = 1, 2, \ldots N; t = 1, 2, \ldots T; s = 0, 1, \ldots L; \varepsilon_{i,t}^{nw} = v_i^{nw} + \epsilon_{i,t}^{nw}$ where v_i^{nw} is the firm-specific fixed effect and $\epsilon_{i,t}^{nw}$ is the stochastic error term. $\Delta nw_{i,t}$ denotes the change in the net worth of i^{th} firm on date t. Our objective is to examine the balance sheet effect of US monetary policy captured by the coefficient of $X_{i,t-s}^{Z}$. In the estimation, we test the hypothesis: $\lambda_q \neq 0$. We allow for alternative data indicators of $X_{i,t-s}^{Z}$ identical to Table 3 and examine the presence and robustness of $'\lambda_q'$ s.

Strengthening the findings of the firm-level relative borrowing estimation, the results of dynamic panel regression reported in Table 5 reveal an inverse relationship between the change in US monetary policy rate and the change in firm's net worth. It emphasizes the non-trivial effect of the US monetary policy transmission on the firm's balance sheet position. First of all, the foreign currency borrowing to asset ratio of firms turns out to be statistically significant with the negative coefficient across all the models. This indicates that the risk of foreign currency exposure can be detrimental to the net worth of the firm. Second, the depreciation of the exchange rate appears to be contractionary with statistical significance. The estimated coefficient of the fed funds rate is also negative and statistically significant. Finally, the estimates of dual and triple interaction variables also fall in line with the theoretical prediction. Going down further for the triple interaction variable, we find that the estimated coefficient is negative and statistically significant for the sub-sample of the post-GFC period. All through the estimation, the estimates of λ_q support the operation of a balance sheet channel of the exchange rate in transmitting international monetary shocks. It is quite likely that the depreciation of the exchange rate originating from a contractionary US monetary policy inflates the repayment burden of the firms, impairing their net worth and hindering access to credit.

Our findings are in line with the theoretical and empirical literature which addresses currency mismatch and balance sheet shocks in the general equilibrium environment (Krugman, 1999; Cespedes, Chang, & Velasco, 2004; Mendoza, 2010; Bianchi, 2011). These models show that a firm's borrowing potential directly depends on the valuation of its collateral or net worth. When the net worth of the firm declines (rises) in an adverse (favourable) economic condition, its borrowing constraint tightens (loosens).

[11] Also, see Kearns and Patel (2016) for the role of the financial channel of the exchange rate in EMEs.

Table 5: Change in Firm's Net Worth for US Monetary Policy Transmission

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	$\Delta nw_{i,t}$	$\Delta nw_{i,t}$	$\Delta nw_{i,t}$	$\Delta nw_{i,t}$	$\Delta nw_{i,t}$	$\Delta nw_{i,t}$
$\Delta nw_{i,t-1}$	0.0657	0.0643	0.0636	0.0207	0.0354	0.0345
	(0.0479)	(0.0480)	(0.0479)	(0.0426)	(0.0376)	(0.0373)
$ln(income_{i,t-1})$	552.3**	577.4**	573.7**	-5.140	-55.12	-40.75
	(281.1)	(282.6)	(281.1)	(210.1)	(219.2)	(307.8)
$ln(pat_{i,t-1})$	0.471***	0.471***	0.474***	0.545***	0.604***	0.537***
	(0.0578)	(0.0578)	(0.0573)	(0.0697)	(0.0781)	(0.0829)
$roa_{i,t}$	1,759**	1,641*	1,609*	-221.0	436.9	-66.91
	(853.1)	(857.9)	(847.2)	(752.0)	(671.9)	(720.5)
$fcbr_{i,t}$	-81.29***	-81.59***	-84.85***	-41.43**	-53.95***	-43.49*
	(26.38)	(26.16)	(26.22)	(19.45)	(20.26)	(23.18)
$gsales_{i,t}$	3.769	3.914	4.271	-1.628	2.493	2.426
	(5.390)	(5.402)	(5.261)	(9.243)	(8.637)	(10.02)
$esr_{i,t}$	8.739	9.265	8.871	1.707	7.496*	4.669
	(5.843)	(5.886)	(5.936)	(4.333)	(4.286)	(5.182)
$inp\_rw_{i,t}$	-0.0315*	-0.0307*	-0.0310*	0.00675	0.00254	0.00194
	(0.0169)	(0.0169)	(0.0167)	(0.0134)	(0.0118)	(0.0132)
Δyg_rate_t	61.48**	27.87	72.00	10.10	-2.265	17.88
	(30.39)	(36.45)	(43.87)	(35.18)	(29.73)	(37.26)
$\Delta infl_t$	173.3***	137.8***	125.5**	137.1***	94.23***	63.66
	(53.26)	(51.96)	(53.21)	(33.73)	(26.49)	(79.00)
$\Delta ln(NER_t)$		-39.30***	-32.03**	-12.70	-23.81**	-21.08
		(15.01)	(15.70)	(14.26)	(11.49)	(27.82)
$\Delta ff\_sh\_rate_t$			-144.9**	-20.19	-48.11	58.91
			(72.86)	(81.96)	(66.00)	(166.6)
$\{\Delta ff\_sh\_rate_t \text{ x } fcbr_{i,t-1}\}$				-8.201*		
				(4.376)		
$\{fcbr\ x\ ner\ x\ ff_{i,t}\}$					-0.868**	-1.115*
					(0.442)	(0.629)
Constant	-2,421	-2,585	-2,545	1,193	1,759	1,424
	(2,592)	(2,601)	(2,589)	(1,972)	(2,052)	(3,063)
AR (1)	-2.40**	-2.39**	-2.39**	-2.27**	-2.32**	-2.31**
AR (2)	0.65	0.64	0.64	0.53	0.51	0.60
Hansen J-statistic	14.98	15.01	14.51	44.79	92.81	62.41
Observations	7,563	7,563	7,563	6,383	6,383	5,102
Number of id	1,338	1,338	1,338	1,205	1,205	1,113

*Note: Standard errors are in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$*

4. Macro-level Evidence on the US Monetary Policy Transmission

Our micro-level analysis robustly identifies the presence of the financial channel of the exchange rate and shows the spillover of US monetary policy to firm-level credit aggregates. Using inferences from micro-level results, we explore the macroeconomic effects of such international monetary transmission. How does the firm-level credit developments influence the economy-wide credit cycles and, more generally, the business cycles? To this end, we use a sign-identified VAR model.

Similar to any other structural VAR model, the SRVAR model requires an explicit identification scheme to identify the exogenous shock of interest. However, these models do not require any short-run, long-run or other point restrictions. Instead, the shocks are identified by imposing a set of restrictions on the sign of impulse responses. Such restriction can be invoked based on the theoretical predictions and/or empirical evidence from the literature. Early SRVAR applications are found in the identification of monetary policy shocks (Faust 1998; Canova, 2002; Canova and De Nicolo 2002; Uhlig 2005, Cantelmo and Melina, 2018). This body of literature is further extended by Dedola and Neri (2007), Pappa (2009), Mountford and Uhlig (2009) and Arias et al. (2018). The use of the SRVAR model to examine the international transmission of the US monetary policy remains relatively unexplored. We exploit this modelling framework to identify the financial channel of the US monetary policy transmission.

For a small open economy like India, changes in US monetary policy – whether endogenous or exogenous from the perspective of US economy - eventually constitute an exogenous foreign monetary policy shock for the Indian economy. Hence, we resort to the partial identification strategy to set up the sign restrictions for our VAR model. We focus on the exogenous variations from the fed funds rate/shadow rate that causes depreciation in the exchange rate and opens up the financial channels of transmission.[12]

4.1 Model Specification

Let us consider the structural form of a VAR (p) model with Z_t $(n \times 1)$ which is specified in equation (3):

$$B_0 Z_t = B_1 Z_{t-1} + B_2 Z_{t-2} + B_3 Z_{t-3} + \ldots + B_p Z_{t-p} + w_t \quad (3)$$

where Z_t is the vector of relevant macroeconomic and financial variables. To generate the reduced form VAR (p), we pre-multiply both sides by B_0^{-1} and obtain:

$$Z_t = A_1 Z_{t-1} + A_2 Z_{t-2} + A_3 Z_{t-3} + \ldots + A_p Z_{t-p} + u_t \quad (4)$$

In the reduced form equation, $A_i = B_0^{-1} B_i$ and $u_t = B_0^{-1} w_t$; $\forall\ i = 1, 2, \ldots p$. The reduced form residual u_t is related to the unknown structural form innovations, w_t, via the impact matrix B_0^{-1}. We assume that w_t follows the standard normal distribution with zero mean and unit variance. To extract the information on the impact matrix and identify the relevant structural shock, we impose restrictions on the sign of the impulse response vector of interest. In the case of the Cholesky decomposition, u_t can be written as $P w_t$ where P is a lower triangular form and variance-covariance matrix is: $\Sigma_u = HH'$. This Cholesky-type identification imposes restrictions on the recursive structure of the underlying structural model by ordering the variables. In the SRVAR model, no such restriction on recursivity is required for the impact matrix**.**

We impose minimal sign restrictions on the variables specific to the financial channel of US monetary policy transmission, which we hypothesize and remain agnostic about the response of key macroeconomic variables of the home economy. The method of identification involves drawing several

[12] In our context, simultaneous identification of other structural or policy shocks to the exchange rate is not required, as we need to disentangle only the US policy rate induced exchange rate fluctuations for our purpose.

orthogonal matrices linking the reduced-form and the structural shocks. We search for a candidate of the matrix B_0 by exploiting the property that any such candidate (say $\tilde{B}_0$) satisfies: $\tilde{B}_0 = QP$; where Q is an orthogonal matrix and P is a lower triangular matrix. The initial P is computed from the reduced form of the estimated variance-covariance matrix of u_t. From the impulse response vector, we select a set of candidate structural model that minimizes a specific penalty function and translates the proposed sign restriction into the impact matrix B_0^{-1}.[13]

4.2 Sign-restrictions for Identification of the Financial Channel of the Exchange Rate

Our firm-level results suggest that the financial channel of the exchange rate, which is in action, can potentially reduce the expansionary effect of depreciation through the trade channel. To throw further light on this channel, we use a fairly simple identification scheme which is presented in Table 6. In the identification scheme, symbol '> 0' denotes positive sign restrictions on the impulse responses with respect to a change in the US monetary policy rate. The symbol '?' implies that we are agnostic about the impulse response of the relevant variable. The restrictions on signs are imposed for one quarter to four-quarter as suggested in the literature (Meinen and Rehoe, 2018).

Table 6: Sign-restrictions for Identification of US Monetary Policy Transmission

Output	Inflation	Relative Credit	Spread	Change in Nominal Exchange Rate	US Monetary Policy Rate
?	?	?	> 0	> 0	> 0

In the spirit of the contractionary devaluation hypothesis and firm-level evidence on the balance sheet effect of US monetary tightening, we impose positive sign restrictions on the corporate bond spread, change in the exchange rate and the US policy rate. However, output, inflation and relative credit variables of the home economy remain unrestricted as it is not obvious if a contractionary foreign monetary policy can cause a contraction for these variables. Hence, we allow the data to determine the impulse responses from the shock. In the baseline model, we consider the short-term/shadow rate as the US monetary policy indicator and use the data matrix $Z_t = [Y_t\ CPI_t\ RLBP_t\ CBS_t\ DEP\_EX_t\ US\_FF_t]'$. We analyze the effect of US monetary policy shock from two dimensions: (i) impulse response function (IRF) analysis and (ii) accumulated effect of the shock. IRF analysis provides an understanding of the impact and propagation of the shock given the identification of the channel of transmission. The accumulated effect enables us to evaluate the quantitative significance of the shock in driving economic fluctuations. We do the robustness test of the results of our baseline model using other indicators of US monetary policy such as the 2-year Treasury yield (US_GS_t) and monetary policy surprises (US_MPS_t).

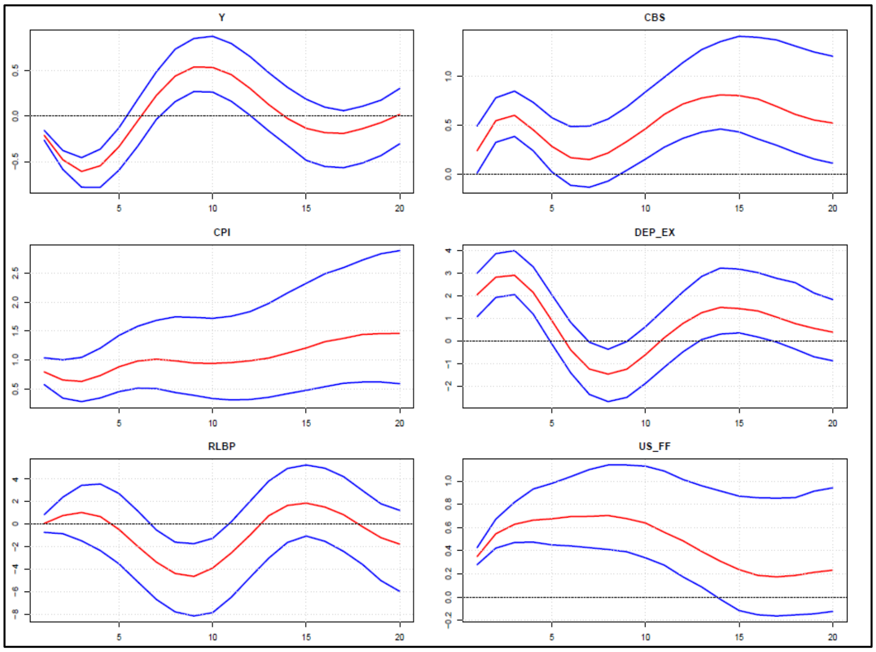
4.3 Results from the Baseline Model

The impulse response plots of the baseline model are presented in Figure 2. It is evident from the plots that the effect of shock on relative credit contraction sets in after a few quarters. The decline in output,

[13] More details on the penalty function of Uhlig (2005) are provided in Appendix 2. See Kilian and Lutkepohl (2017) for the alternative forms of the SRVAR models.

however, shows up almost immediately. It falls below the long-run level at the impact and takes more than a couple of years to recover. The fall in output is accompanied by a strong positive response of CPI inflation which persists steadily over the periods. Such contraction of output along with a rise in inflation exhibits a cost-channel effect of the international transmission of the US monetary tightening.

Figure 2: Impulse Responses of a Positive Shock to US fed funds rate



The positive shock to US monetary policy rate raises the cost of capital for the domestic firms. It translates through a conspicuous rise in the exchange rate and corporate bond spread of the home economy. The rise in spread reflects the tightening of the domestic financial conditions and underlines the financial channel of transmission of the foreign monetary impulse to the relative credit variable. The depreciation of the exchange rate, unlike spread, creates a two-pronged effect on the output simultaneously. It makes a cost-push impact that contracts the output with immediate effect as well as triggers the financial channel, leading to a contraction in output via credit aggregates and thereby elongating the downswing with a lag. In sum, we find that a positive shock to US interest rate leads to a slump in domestic business and credit cycles and generates upward pressures on inflation through the cost-channel.

4.4 Robustness Tests of Impulse Response Properties

We conduct robustness tests of the properties of impulse responses obtained from the baseline model. To this end, the baseline model is re-run with the alternative monetary policy indicators of the US. We replace US_FF in the data matrix Z_t by US_GS and US_MPS, one at a time, then re-estimate the SRVAR model and compare the resultant impulse response functions with the baseline. In the baseline model, the shock to the short-term/shadow fed funds rate refers to the conventional series of policy innovations over the short horizon. However, the same for the 2-year Treasury yield and monetary policy surprises represent innovations to a more comprehensive set of monetary policy instruments (including "forward guidance") over a longer-term horizon. Although the quantitative implication of the shock alters, it is observed that the qualitative pattern of the IRFs remains unchanged. In Figure 3 and 4, the IRF plots under the alternative US monetary policy indicators are presented.

Figure 3: Impulse Responses of a Positive Shock to 2-year US Treasury Yield

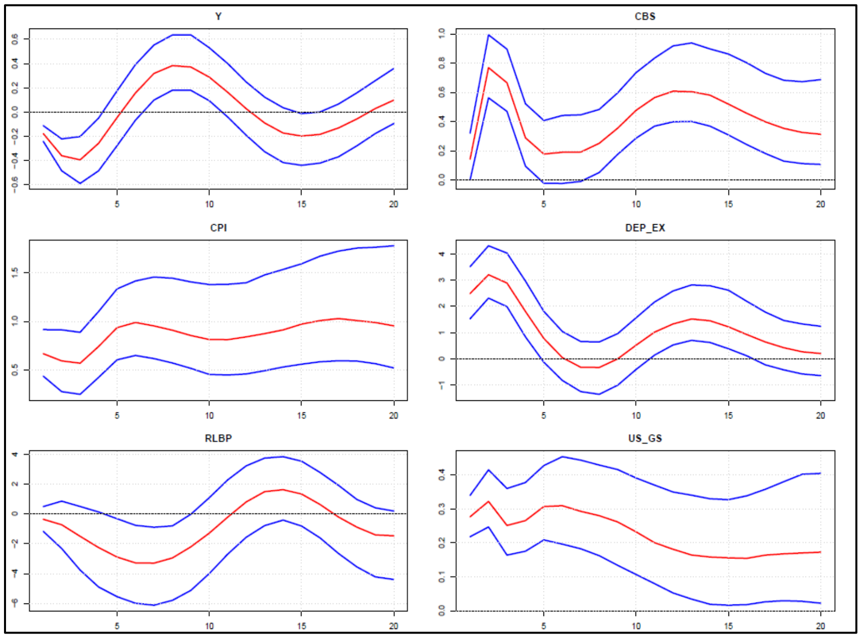
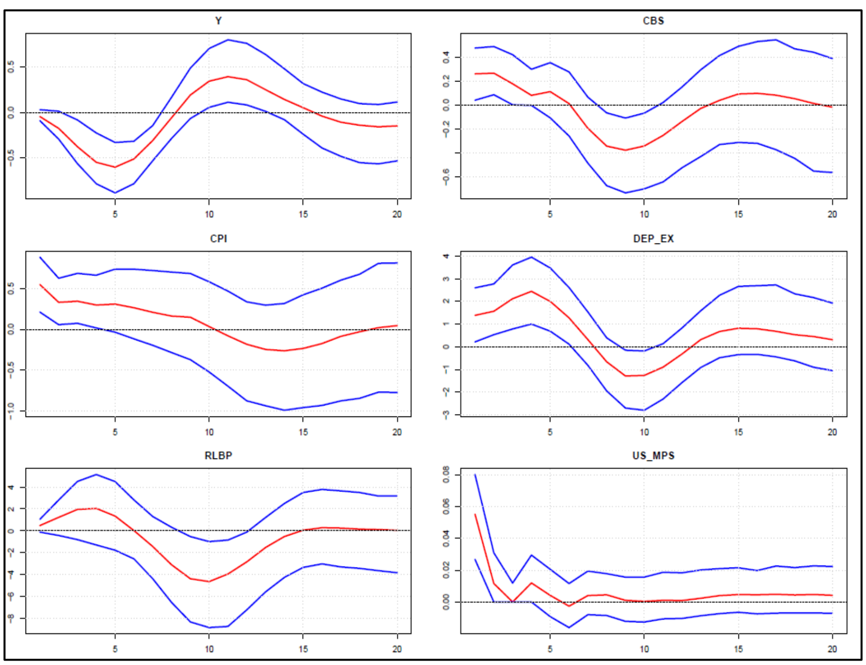


Figure 4: Impulse Responses of a Positive Shock to US Monetary Policy Surprise



For the 2-year US Treasury yield, the impulse response of the relative credit variable shows statistically significant and prolonged contraction with a relatively faster rate of adjustment than the baseline case. The contraction in real output accentuates and a significant rise in CPI inflation is noticed. In the case of the Gertler-Karadi type monetary policy surprise indicator, the relative credit declines with a lag and the peak effect of contraction are dampened to some extent compared to the earlier cases. Output goes through a downturn along with a statistically significant uptick in the inflation rate.

Overall, the macro-level evidence on the effects of the positive shock to US policy instruments is consistent with the micro-level inferences. The properties of IRFs stand robust to the alternative indicators. The results show that, in presence of the financial channel of the exchange rate, US monetary tightening can engender a supply-side contractionary effect similar to Ravenna and Walsh (2007).

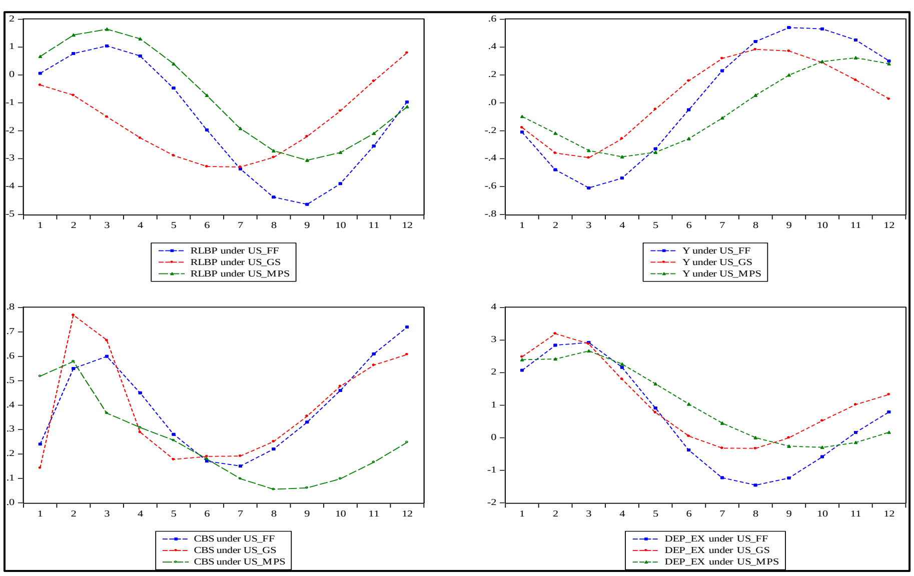
4.5 Comparing the Contraction of Business and Credit Cycles across Alternative Models

Given the fact that there is a quantitative difference in the macroeconomic effects of the shock to the US monetary policy rate across the indicators, we compare them based on the accumulated effects. The magnitude of contraction for one per cent positive shock to US policy interest rate is computed from the accumulated effect of the shock for the periods of statistically significant IRFs for the exchange rate, spread, credit, output and inflation. The results are presented in Table 7.

Table 7: Accumulated Effects (in percentage) of One per cent Contractionary US Monetary Policy Shock

Variables	*US_FF*	*US_GS*	*US_MPS*
Exchange rate Depreciation	3.81	7.84	1.63
Corporate Bond Spread	0.74	1.44	0.29
De-trended Relative Credit	-6.59	-10.34	-1.96
De-trended Real Output	-0.76	-0.87	-0.21
CPI Inflation	1.30	2.47	0.44

Figure 5: Comparison of Contraction of Credit and Output under Alternative US Monetary Policy Indicators through Financial Channel of Exchange Rate



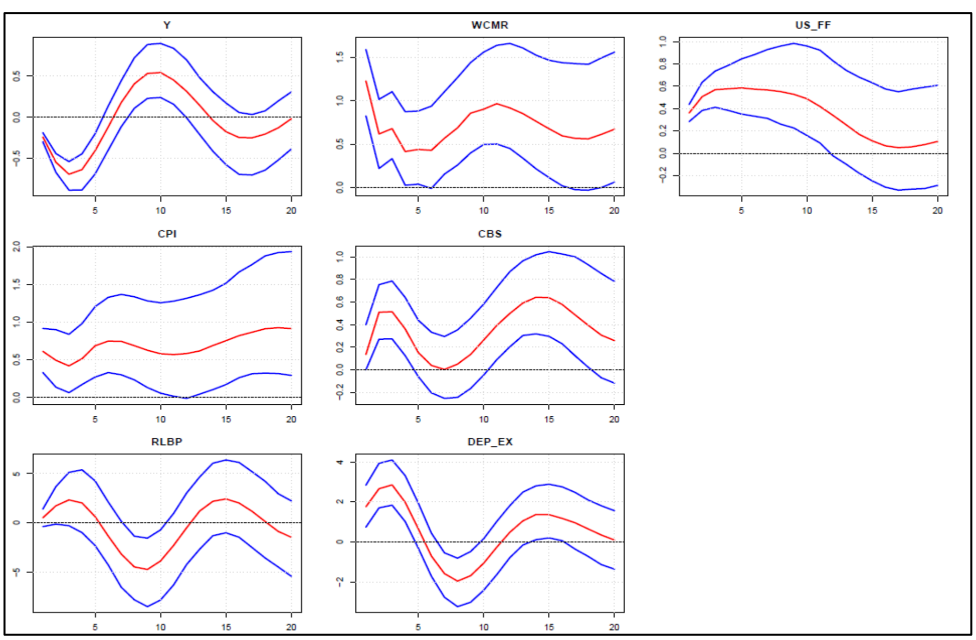
One notable feature of the results is the role of the exchange rate and domestic spread in amplifying the foreign monetary policy shock. Under all three monetary policy indicators, the shock leads to a sizeable depreciation of the home currency and an escalation of domestic bond spreads. It implies that exchange rate depreciation accompanying the shock leads to a rise in the risk premium and a tightening of the internal borrowing constraint for firms. This precipitates a decline in credit and output. It is apparent that the depreciation of the exchange rate and the rise of spread are higher in the case of a shock to the 2-year US Treasury yield and lower for the monetary policy surprises. Accordingly, one can find that the contractionary effects of the US monetary tightening on credit and output magnify under the long-term policy indicator compared to the short-term policy indicators. To highlight this point, we present the median impulse responses of the relative credit, output, exchange rate and spread in Figure 5.

On the whole, the comparison of results across models underscores the fact that a change in US long-term interest rates has the potential to be accompanied by stronger cross-border spillover effects on EMEs than a similar change in the short-term rate. These results are consistent with observed financial market reaction to a large US monetary policy shock such as the "Taper Tantrum" episode in 2013, in which many EMEs experienced a rapid depreciation of their exchange rates and strong rise in bond spreads, precipitating a prolonged period of weak credit and output growth.

4.6 Exploring Monetary Policy Action of the Home Economy

While investigating international transmission of US monetary policy through the financial channel of the exchange rate, it is quite relevant to check if the domestic monetary authority plays any role via its policy instrument. In doing so, we remain agnostic about the nature of the policy response by the Reserve Bank of India (RBI). Since the RBI can respond to the shock by using its policy rate and various quantitative instruments at its disposal (e.g., reserve requirement on banks and balance sheet tools), we proxy its policy stance by the weighted call money rate which is a summary measure of the relative tightness of liquidity in the banking system. We re-estimate the baseline model by adding this additional variable in the data matrix while maintaining identical sign restrictions. The IRF plots are presented in Figure 6.

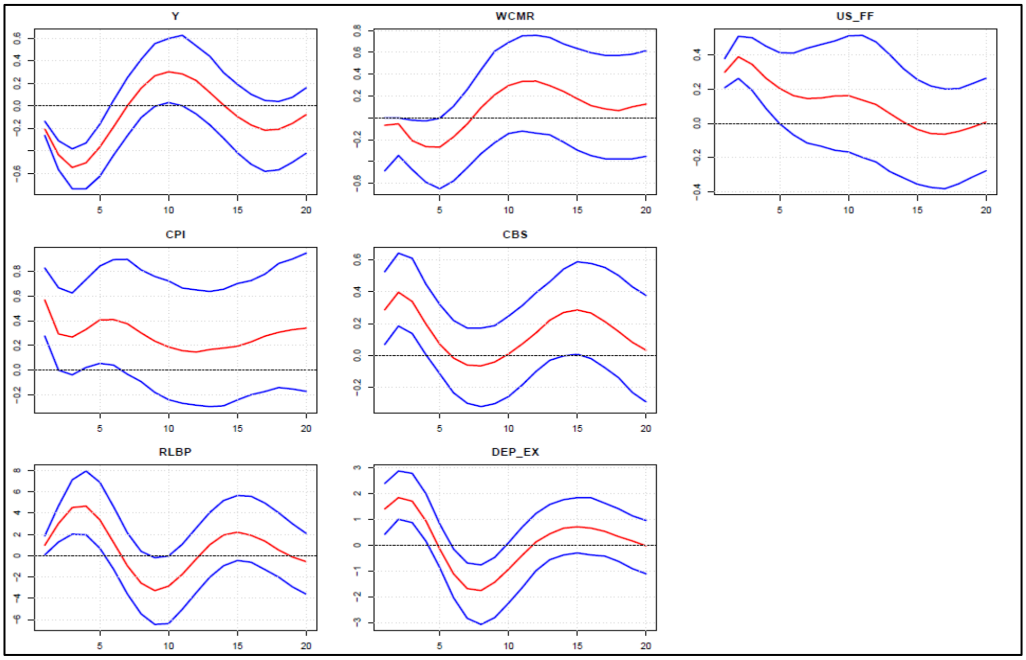
Figure 6: Effects of US Monetary Policy Shock for Baseline Model with Domestic Policy Rate



The impulse response shows that the call money rate shoots up high in response to US monetary tightening almost instantaneously. This is suggestive of the evidence that the RBI endeavours to arrest the exchange rate depreciation by raising its policy rate.[14] A higher short-term rate significantly reduces the rate of currency depreciation and slows down the credit contraction. But, as should be expected, it comes at the cost of increased output contraction, reflecting tighter domestic monetary conditions. This result is in line with the literature suggesting that global factors, such as US monetary policy, tend to have a significant influence on movements in longer-term bond yields in EMEs, causing significant output fluctuations in these economies (Obstfeld, 2015; Miyajima et al. 2015, Chatterjee, 2016).

In this context, we perform a counterfactual experiment with credit easing monetary policy for the home economy. Our motivation is to examine if the domestic credit channel, with due support from interest rate easing, can generate an expansionary effect to offset the contractionary impact of the financial channel of the exchange rate. We impose a negative sign restriction on the domestic policy rate and compare the results with the baseline model. The IRF plots are provided in Figure 7.

Figure 7: Effects of US Monetary Policy Shock for Baseline Model with Negative Sign-restriction on Domestic Policy Rate



The overall pattern of the IRFs remains unaltered except for the domestic policy rate and relative credit. The qualitative feature of the IRF plot for relative credit indicator alters due to interest rate easing policy intervention of the monetary authority. It is noticeable that the domestic credit expands much faster relative to the external credit for the period of impact and sustains nearly for six quarters. This stands in sharp contrast with the baseline IRF plot of the relative credit indicator.

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[14] The pattern of IRF plot of the domestic policy rate holds even in the case of longer-term hardening of policy stance under 2-year US Treasury yield. Domestic monetary authorities are likely to give more weights to longer-term interest rates in designing an appropriate response to international monetary shocks.

Table 8: Accumulated Effect (in percentage) of One per cent Contractionary US Monetary Policy Shock

Variables	*Without Sign Restriction on WCMR*	*With Negative Sign Restriction on WCMR*
Exchange Rate Depreciation	2.90	2.80
Corporate Bond Spread	0.54	0.77
De-trended Relative Credit	-6.20	10.75
De-trended Real Output	-0.83	-1.35
CPI Inflation	1.10	1.37
Call Money Rate	1.20	-0.63

On the quantitative side, the usual contractionary effect of the US monetary tightening still prevails and gets intensified compared to the baseline case. For illustration, in Table 8, we compare the accumulated effects under two scenarios - with and without negative sign restriction on the domestic policy rate. Compared to the monetary tightening scenario, the monetary easing scenario delivers an expansion of domestic credit vis-à-vis external credit but fails to slow down the output contraction due to pressures from the cost channel and financial channel reflected from the uptick in spread and inflation. Hence, it appears that the revival of the domestic credit cycle through interest rate easing monetary policy may not be an optimal policy to bring respite for the home economy.

5. Conclusion

Over the past decade, many EMEs have experienced rapid growth of dollar debt in the corporate sector together with large depreciation of their currencies against the dollar and subdued macroeconomic performances. This has renewed the classic debate about contractionary devaluation that became popular in the 1990s and 2000s. Our paper is an attempt to shed empirical light on this hypothesis using the Indian economy as a case study. We document evidence on the financial channel of the exchange rate and its impact on firms' borrowing behaviour and macroeconomic performance using both firm-level and macro-level analyses.

Our results suggest that the exchange rate has a significant effect on Indian non-financial firms' net worth and their access to credit. Credit conditions for firms typically tighten with tighter US monetary policy and larger depreciation of the rupee against the dollar. While our post-GFC sample is relatively short, our evidence, nonetheless, suggests that this negative impact remained quite strong, coinciding with the rapid growth in foreign currency borrowing by the Indian non-financial firms. The combination of higher US interest rates, a strong dollar and heightened global aversion has the potential to create severe disruption in credit conditions in EMEs. We find that the domestic credit cycle in India goes through a pronounced downswing nearly for six to eight quarters following US monetary tightening, leading to a contraction in output.

One key question is the extent to which EMEs should respond to the destabilising effects of the external monetary shocks. Given its simple structure, our model does not provide the scope to explore options that could involve multiple instruments to address the contractionary effects of currency depreciation. Our results, nevertheless, demonstrate the familiar dilemmas facing monetary authorities in small open economies. While countering US monetary tightening by higher domestic interest rates may be desirable to stem rapid currency depreciation, it is likely to come at the cost of higher output volatility. We explore a counterfactual scenario where the domestic monetary authority responds to US monetary tightening by reducing its own interest rates. While an easier domestic monetary policy is seen to be effective in boosting domestic credit, it is unlikely to reduce the contractionary effects of US monetary tightening.

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Appendix 1: Data on Firm-specific Variables and Macro-financial Indicators

Description of Variables for Firm-level Analysis

Total liability is the sum of all the resources deployed by the firm. It includes all sums it owes to the shareholders in the form of share capital and reserves and surpluses, sums it owes to its lenders inclusive of secured and unsecured loans and the current liabilities and provisions. External commercial borrowing indicator is the sum of both secured and unsecured external commercial borrowings of the Indian companies. Domestic borrowing is the difference between total borrowing and external commercial borrowing.[15]

Net worth consists of the monies put into the company by the equity shareholders in the form of equity capital and the profits generated and retained as reserves by the company. Net profit of the company after tax is the residual after all revenue expenses are deducted from the sum of the total income and the change in stocks. Total income is the sum of all kinds of income generated by an enterprise during an accounting period. It includes income generated from the sale of goods as well as services; income from investment activity; extraordinary or exceptional income; and other incomes. Return on assets (roa) is computed as the logarithm of income to asset ratio, where total asset refers to the sum of all current and non-current assets held by a firm as on the last day of an accounting period. The data on sales include all regular income generated by companies from the identifiable sale of goods and non-financial services.

Export to sales ratio (*esr*) captures the export earnings through exports of goods and services which are measured as a percentage of sales. This ratio provides a measure of the degree of exposure of a company to export markets, i.e. how much business a company generates by catering to export markets. This data field of input purchases shows the percentage of raw material imports in the total raw material purchases during the year. Since the raw material is the major expense for a manufacturing enterprise, this ratio measures the sensitivity of a company's cost structure to adverse movements in exchange rates and/ or customs duty.

Finally, we construct two interaction variables. The first is a dual interaction variable which is expressed as the product of the change in the nominal exchange rate and the actual/shadow fed funds rate: ($fcbr_{i,t-1}$ x $\Delta ff\_sh\_rate_t$). The second is a triple interaction variable ($fcbr\ x\ ner\ x\ ff$) which is defined as the product of (i) the last period's share of foreign currency borrowing in the total asset ($fcbr_{i,t-1}$), (ii) the change in the current period actual/shadow fed funds rate ($\Delta ff\_sh\_rate_t$), and (iii) the change in the current period nominal exchange rate ($\Delta ln\{NER_t\}$). These interaction variables can potentially capture the international transmission of US monetary policy through the exchange rate channel and its amplification via firms' exposure to foreign currency debt.

Description of Macro-financial Indicators for Macro-level Analysis

In the case of the macro-financial indicators, descriptions and sources of the data are mentioned in Table A.1. The time-series patterns of the relevant variables are presented in Figure A.1. Output and credit variables are de-seasonalised and passed through business cycle filters. Deviations of these variables from

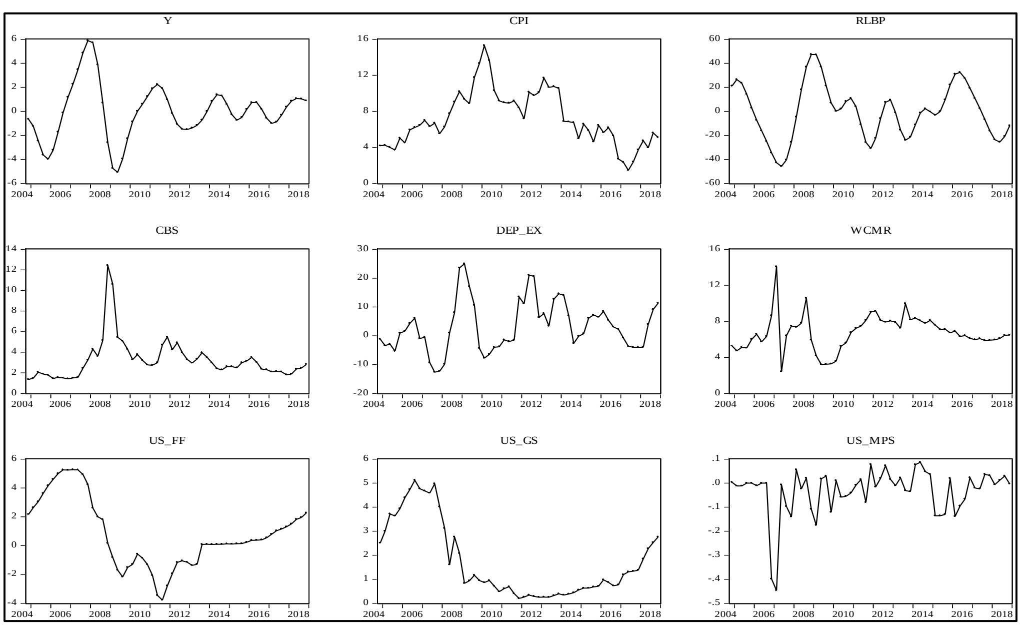
[15] Total borrowing captures the outstanding value of long-term borrowings, short-term borrowings, current maturities of long-term debt and lease, and is the sum of different types of borrowings of a company.

their trends are expressed in percentage term. We also use the seasonally adjusted consumer price inflation and change in the nominal exchange rate. The daily interbank borrowing rate (the call rate) is used as the proxy for the domestic policy rate, given the fact that the Reserve Bank of India (RBI) manages this rate actively using its interest rate corridor system. The corporate bond spread is chosen as the measure of risk premium in the domestic credit market. The interest rate variables are not subject to any data treatment.

Table A.1: Description and Sources of Macro-financial Indicators

Variable Description	*Source*
Production of total industry (Y), Index 2015=100	St. Louis FRED
Consumer price inflation (CPI) for Total - All Items, (Index 2015=100) y-o-y basis	St. Louis FRED
Weighted average call money rate ($WCMR$)	HBS: Table No. - 177; DBIE, RBI
Non-food credit provided by Scheduled Commercial Banks (NFC)	DBIE, RBI
External commercial borrowing (ECB) inclusive of automatic and approval routes	RBIB Table No. – 37
Cyclical component of Relative Credit indicator ($RLBP$)	Author’s calculation
Change of nominal exchange rate (DEP_EX)	St. Louis FRED
Effective federal funds Rate (US_FF) adjusted with negative shadow rate	St. Louis FRED
2-year US Treasury yield (US_GS)	Bloomberg
US monetary policy surprise (US_MPS)	Gertler and Karadi (2015)
Corporate bond spread (CBS), CEMBI Broad, India, Strip spread, in basis points, period average	JPMorgan Chase

Figure A.1: Time Series Plots of Macro-financial Indicators



Appendix 2: Identification procedure by penalty function approach of Uhlig (2005)

Let J and K are the total numbers of sign restrictions and response periods, respectively, for which the restrictions apply. Suppose, the impulse response vector, denoted by α, is the vector that minimizes the total penalty $\Psi(\alpha)$ for all constrained responses $j \in J$ at all constrained response periods $k \in K$. Considering all failures across the impulse responses symmetrically, the penalty function is adjusted for the scale of the variables and sign of the restrictions. Treating the signs equally, let $l_j = -1$ if the sign of the restriction is positive and $l_j = 1$ if the restriction is negative. If $r_{j,\alpha}(k)$ be the response of j at response step k to the impulse vector α, then the minimization problem is written as:

$$\min_{\alpha} \Psi(\alpha) = \sum_{j \in J} \sum_{k \in K} b \cdot f\left[l_j \left(\frac{r_{j,\alpha}(k)}{\sigma_j}\right)\right] \text{.............................} (5)$$

where b is a penalty depending on a $f(\cdot)$ such that,

$$b = 1 \text{iff}\left[l_j \left(\frac{r_{j,\alpha}(k)}{\sigma_j}\right)\right] \leq 0$$

$$= penalty \text{ if } f\left[l_j \left(\frac{r_{j,\alpha}(k)}{\sigma_j}\right)\right] > 0 \text{ ....} (6)$$

Note that the penalty is a non-zero scalar. The impulse response vector is extracted by minimizing the total penalty for the restricted variables at all restricted horizons.

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