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International Spillovers of U.S. Monetary Policy

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Abstract

We estimate a structural dynamic factor model on large panel quarterly data to analyse the spillovers of U.S. monetary policy to the advanced economies and emerging and frontier market economies. The estimated model suggests that monetary contraction in U.S. leads to a significant decrease in real GDP with typical inverted hump-shape almost for all countries. It reduces permanently aggregate price level, increases interest rate and leads appreciation of U.S. dollar. However, contagion of U.S. monetary policy to the individual countries shows heterogeneity. For instance, its impact is larger in developing countries. We also find that global financial crisis has amplified the impact of U.S monetary policy on the rest of world in particular on developing countries. Lastly, the empirical results suggest that the cross-country heterogeneity in responses may be consequence of difference in country-specific characteristics such as exchange rate regimes, currency of price settings of firms, central bank independence and geographical distance from Unites States.

Keywords: international monetary spillovers; structural factor model; cross-country heterogeneity; country-specific characteristics

JEL Classification: C38, E43, E52, E58, F42, G12

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1 Introduction

The global financial crisis and strong linkage across countries increase the relevance of international spillovers of global shocks with U.S. monetary policy in particular reflecting a disproportionately large size and degree of interconnectedness with the world. Because there is a broad consensus that spillovers flowing out from the U.S. are relatively large (see IMF (2013) and IMF (2014)), it has even been argued that U.S. monetary policy is one of the main determinants of the "global financial cycle[1]" which is more aligned with uncertainty and change in risk aversion of the markets rather than countries' specific macroeconomic condition (Bekaert et al. (2013), Miranda-Agrippino and Rey (2015), Bruno and Shin (2015)).

In this context we aim to answer the following questions in this paper. First, does U.S. monetary policy have a significant effect on the main macroeconomic variables of other countries? Second, do these effects differ across countries, across regions and across different economic levels? If yes, what is the source of these differences across countries? Are they related to the country-specific characteristics? Third, how do spillovers from U.S. monetary policy vary in normal times versus in crisis times? In other words, do spillovers from conventional U.S. monetary policy differ from the unconventional U.S. monetary policy?

Some of these questions have already been studied in the economic literature. We differentiate from other studies in the following aspects. First, most of the studies in the literature largely use small-scale models such as Kim (2001), Canova (2005), Cushman and Zha (1997) and many others. Using a small number of variables may not be fully adequate to identify shocks properly and complete structural analysis. Furthermore, it is well known that central banks and other policy institutions are interested in this and publish a large number of variables, which suggests that these variables contain noteworthy information about the state of the economy. So, an econometric model that uses less information than what agents have may be problematic for analysing the impact of structural monetary policy shocks, as discussed in Giannone et al. (2005). We address these issues by placing a structural dynamic factor model on a large panel of data set.

Unlike VAR models, this model provides an appropriate and powerful approach for policy analysis, since it uses sufficient information to recover the space spanned by structural economic shocks, without the limitations of the dimensionality problem. To the best our knowledge, this is one of the first papers to use a structural dynamic factor model to investigate international spillovers from the U.S. monetary policy shocks to rest of the world. Second, most of the previous studies focus on a limited number of countries (Mackowiak

[1] Global financial cycles are associated with surges and retrenchments in capital flows, booms and busts in asset prices and crises (see Rey (2015).

(2007) on eight emerging markets, Kim (2001) on non-U.S. G7 countries and Kazi et al. (2013) on OECD) or on pre-crisis or post-crisis periods. In this study, we use a large panel of data for 19 developed and 12 developing countries between 1979-2013. Finally, this study does not emphasise only spillovers from U.S. monetary policy, but it attempts to explain empirically cross-country differences in spillovers by country-specific characteristics.

In a recent, independently developed paper, Dedola et al. (2017) attempts to answer similar questions for a large data set by using country-characteristics in a way that is most similar to our study. They used a two-step approach: first, they identified monetary policy shocks imposing sign restrictions to VAR, and then they computed impulse responses by estimating a simple autoregressive model using shocks obtained in the first step for each country. They found similar significant and heterogeneous responses to U.S. monetary shocks but no systematic relations between responses and the most likely country-specific characteristics.

Our study differs primarily by identification approach and estimation method of model and impulse-responses. As discussed in the empirical macroeconomic literature, the difference in identification turns out to be important for structural analysis[2]. Dedola et al. (2017) endogenously identify shocks using on sign restrictions in a 13-variable monthly Bayesian VAR. In the present study, we employ a novel method suggested by Stock and Watson (2012) and Mertens and Ravn (2013) in a data-rich environment to avoid the cost of the imposition of disputable restrictions and the potential measurement error in the narrative approach[3]. The narrative monetary policy shock for U.S. measured by Romer and Romer (2004) is used as a proxy for the structural monetary policy shock. The obtained shocks series by Dedola et al. (2017) seem somewhat too persistent and suffers from using inadequate information to recover the space spanned by structural economic shocks.

We find that U.S. monetary policy has significant effects on the main macroeconomic variables in developed and developing countries. In line with the existing literature, contractionary U.S. monetary policy shock leads to a significant decrease in all other countries' real GDP and prices with a typical inverted hum-shaped like U.S. real GDP. However, its impact is larger in developing countries. A shock increasing the federal funds rate by 50 basis points increases interest rates by around 200 basis points in developing countries and by around 25 basis points in developed countries. Relatively larger increases in developing countries' interest rates lead to greater appreciation of the U.S. dollar against domestic currencies. We also find that the global financial crisis has amplified the impact of U.S monetary policy on

[2]Canova (2005) discuss the consequence of misidentification when extracting structural shocks in VAR models; and Ilzetzki et al. (2017) discuss the impact of the structural monetary and fiscal policy shocks obtained from different identification approaches.

[3]Narrative approach is one way of identifying monetary policy based on careful reading of the minutes of the FOMC in the literature.

the rest of world, in particular, in developing countries.

The empirical results suggest that cross-country heterogeneity in responses to the same U.S. monetary policy shock are related to country-specific characteristics including the exchange rate regime, currency choice of price settings of firms, central bank independence and geographic distance from United States. For example, the average reaction of real GDP, prices and interest rates in economies with a floating exchange rate regime are smaller when compared to non-floaters. The results of this study suggest that economies could mitigate the spillovers from U.S. monetary policy by changing their country-specific characteristics in the long run.

The rest of the paper is organised as follows: Section 2 introduces a description of econometric methodology and identification of U.S. monetary policy. Section 3 presents the data used in the estimation. Section 4 presents estimated international spillovers from U.S. monetary policy to rest of the world. It continues by discussing the role of country-specific characteristics in explaining cross-country heterogeneity in the spillovers of U.S. monetary policy. Section 5 describes the results from a number of robustness checks regarding the dynamic factor model specification, identification and sub-samples. The final section concludes.

2 The dynamic factor model

Let $X_t = [x_{1,t},\ x_{2,t}, ...,\ x_{n,t}]$ denote a stationary n-dimensional vector where $t = 1, ..., T$, is standardised to mean zero and unit variance. Each stationary variable x_{it} can be decomposed into the sum of two mutually orthogonal unobserved common component χ_{it} and the idiosyncratic component ε_{it} :

$$X_t = \chi_t + \varepsilon_t, \qquad \varepsilon_t \sim i.i.d.\ N(0, Q) \tag{1}$$

where Q is diagonal matrix. It is assumed that the idiosyncratic component is normally distributed and uncorrelated with χ_t at all leads and lags. The common component is a linear combination of factors F_t :

$$\chi_t = \Lambda F_t = \lambda_{1i} f_{1t} + \lambda_{2i} f_{2t} + ... + \lambda_{ri} f_{rt} \tag{2}$$

where $F_t = [f_{1t},\ ...,\ f_{rt}]$ is an $r\ x$ 1 vector of unobserved common factors (static factors) and Λ is $n \times r$ matrix of factor loadings. We assume that common factors follow VAR process of order p:

$$F_t = \Phi_1 F_{t-1} + \Phi_2 F_{t-2} + ... + \Phi_p F_{t-p} + \epsilon_t, \tag{3}$$
$$\epsilon_t = R u_t$$

where $\Phi_1, .., \Phi_p$ are $r \times r$ matrix of autoregressive coefficients, R is a rxq matrix and u_t is a q-dimensional vector of orthonormal white noises with $q \leq r$. These white noises are structural macroeconomic shocks or "dynamic factors" .

2.1 Identification of structural shocks

By plugging (3) and (4) in (1), the system can be written in the dynamic form (moving average representation of the structural form):

$$X_t = b(L)u_t + \varepsilon_t, \tag{4}$$

where $b(L) = \Lambda\Phi(L)^{-1}R$ is impulse response functions where $\Phi(L) = (I - \Phi_1 L - ... - \Phi_p L^p)$.

Impulse response functions are not identified in the DFM-MA representation (4). As is well-known from the structural VAR literature, a suitable qxq orthogonal rotation matrix is the only way to achieve identification. In order to identify structural shocks with zero restrictions on the contemporaneous impact matrix, the long run impact matrix and sign restrictions strategy are used in the standard macroeconometrics literature[4].

In this study we identify monetary policy shocks using a novel method that approaches exogenous shocks as external instrumental variables following a novel method suggested by Stock and Watson (2012) and Mertens and Ravn (2013) [5]. The math of this new identification for the case of a single instrument is summarized as below. The equations used in this section are inspired by Stock and Watson (2012).

We assume that the r innovations ϵ_t are linear combinations of structural shocks u_t, so that

[4] Moreover, see Stock and Watson (2005) for discussion of identification in dynamic factor models; and Uhlig (2005) and Eickmeier (2009) for sign restrictions strategy

[5] We also apply a recursive identification scheme based on zero restrictions following Forni and Gambetti (2010). Note that details of this approach will be discussed later in the section 5

$$\epsilon_t = Ru_t = [R_1 R_2 ... R_r] \begin{bmatrix} u_{1t} \\ ... \\ u_{rt} \end{bmatrix} \tag{5}$$

where $R_1$is the first column of R, u_{1t} is the first structural shock. We assume $\Sigma_{\epsilon\epsilon} = R\Sigma_{uu}R'$, where $\Sigma_{\epsilon\epsilon} = E(\epsilon_t \epsilon_t')$ and $\Sigma_{uu} = E(u_t u_t')$.The system described above is invertible and so structural shocks can written as a linear combination of innovations: $u_t = R^{-1}\epsilon_t$.

In order to compute impulse response function, we only need to identify R_i where the interested variable is at ith order. Define the single instrumental variable Z_t which satisfies the following assumptions:

(i) $E(\epsilon_{1t} Z_t) = \alpha \neq 0$ (relevance to the interested shocks)

(ii) $E(\epsilon_{jt} Z_t) = 0, j = 2, .., r$ (exogeneity: uncorrelated with other structural shocks)

(iii) $\Sigma_{\epsilon\epsilon} = D = diag(\sigma_{\epsilon_1}^2, ..., \sigma_{\epsilon_r}^2)$ (uncorrelated shocks: the structural shocks are uncorrelated)

condition (i) and (ii) imply that

$$E(u_t Z_t) = E(R\epsilon_t Z_t) = [R_1 R_2 ... R_r] \begin{bmatrix} E(\epsilon_{1t} Z_t) \\ ... \\ E(\epsilon_{rt} Z_t) \end{bmatrix} = R_1 \alpha \tag{6}$$

The instrument Z_t identifies R_1 up to scale and sign. The shock ϵ_{1t} is identified (up to scale and sign) by further imposing condition (iii), which implies that $\Sigma_{uu} = RDR\prime$. Define Π to be the matrix of coefficients of the population regression of Z_t on u_t. Then, under conditions (i) through (iii),

$$\begin{aligned} \Pi u_t &= E(Z_t u_t')\Sigma_{uu}^{-1} u_t = \alpha R_t'(RDR')u_t \\ &= \alpha(R_t' R'^{-1})D^{-1}(R^{-1}u_t) = (\alpha/\sigma_{\epsilon_1}^2)\epsilon_{1t} \end{aligned} \tag{7}$$

where $\mathrm{R}^{-1}R_1 = e_1$, where $e_1 = (1, 0, ..., 0)'$ so $\alpha(R_t' R'^{-1})D^{-1} = (\alpha/\sigma_{\epsilon_1}^2)e_1'$.

Equation (6) displays the result anticipated in the opening sentence of this subsection: the shock identified using the instruments Z_t is the predicted value from the population regression of Z_t on the innovations u_t, that is, Πu_t, up to scale and sign. The scale and sign of ϵ_{1t} and $_1$ are set by normalising the shock to have a unit impact on a given variable.

The structural shock is estimated using the sample analogue of equation (6); that is, $\hat{\epsilon}_{1t}$ is computed as the predicted value of the sample regression of Z_t on $\hat{u}_t$, where $\hat{u}_t$ is the vector of residuals from the reduced-form VAR estimated using $\hat{F}_t$. If Z_t is available only for a subperiod, the coefficients of this regression are used to compute the predicted values for the span for which $\hat{u}_t$ is available but Z_t is not.

The narrative monetary policy shocks for U.S. measured by Romer and Romer (2004) are used as the external instrumental variable. The instrument is correlated with the shock of interest but uncorrelated with all other structural shocks.

3 Data

The data set is divided into two blocks: data related to the U.S. economy[6] and data from the rest of the world. We use Stock and Watson's large data set for the U.S. economy. This data set includes 140 individual quarterly series from 1979Q2-20015Q2: GDP, industrial production and components, CPI, PPI, monetary aggregates, banking, housing sector, productivity and cost, interest rates, exchange rates, employment, business, and financial markets data. For the rest of the world, we mainly use the GVAR data set containing 30 countries. This data set contains main macroeconomic variables: real GDP, CPI, short-term interest rates and real exchange rates for the same time period. The selected period of analysis depends purely on data availability outside the U.S. In order to make better sense of co-movements across countries, countries are divided into six regional groups - North America, Latin America, Europe, Asia, Australasia, and Others and two groups according to their level of economic development - developing and developed countries[7].

We adopt "light transformation", as in Bernanke et al. (2005) and Forni and Gambetti (2010). We first use the differences in the log of prices, real GDP and monetary aggregates (rather than the second differences of logs), the log of real exchange rates and keep interest rates in level (rather than the first difference). The full description of variables, including the list of the series, the source of the data and the applied transformations is provided in the Appendix 7.5.

All data are seasonally adjusted and outliers are removed. All transformed series are demeaned and standardised. We account for structural breaks in the mean when all series are demeaned. Breakpoints in the mean are detected by applying the sequential multiple breakpoint testing procedure used by Bai and Perron (2003) and these shifted means are subtracted from the series[8].

We regress several country-specific characteristics on estimated impulse responses and

[6]Note that we include several global external variables that are not related to the individual non-U.S. economy but behave like U.S. variables, such as OECD growth and world oil production in this block. See data Appendix 7.5 for details.

[7]For the list of countries in regional groups and economics level groups, see Appendix 7.5.

[8]Break dates are available upon request.

impulse responses according to them, in order to discuss the role of country-specific characteristics in cross country heterogeneity.

The exchange rate regime classification comes from Ilzetzki et al. (2017), which is an updated version of the Reinhart-Rogoff exchange rate regime classification based on market data. We grouped the European Union countries differently, as a new category that pegged different currencies rather than US Dollar like German Mark. The degree of exchange rate pass-through is the computed exchange rate pass-through on import prices using micro-foundations of pricing behaviour by exporters, following Campa and Goldberg (2005) and as reported in the Appendix 7. The central bank independence measure devised by Crowe and Meade (2007) is used as a proxy for central bank independence. Logs of geographical distance from the U.S. and trade tariffs are used as a proxy for measuring trade costs that affect import prices.

4 The empirical analyses:

In this section, we present the preliminary analyses conducted prior to the estimation of the empirical results. We first report the selection process of the number of factors and the assessment of estimated factors. Then, we estimate impulse response functions with forecast error variance decomposition to contractionary U.S. monetary policy, following how the model fits the data. Finally, we discuss the heterogeneity of U.S. monetary policy transmission to across countries and the role of country-specific characteristics.

4.1 Latent factors

The number of static factors, r, that span the factor space is an important choice in factor analysis. We selected the optimal number of factors using an information criteria approach. The idea is to choose the number of factors that will maximises the general fit of the model using a penalty function to account for the loss in parsimony. Bai and Ng (2002)' seminal paper derived information criteria to determine the number of factors in approximate factor models when the factors are estimated by principal components. In this study, we use different panel information criteria (PC_{p1}, PC_{p2}, PC_{p3}, IC_{p1}, IC_{p2}, IC_{p3}) developed by Bai and Ng (2002) and Onatski (2010)[9]. The latter criticises the Bai-Ng criteria as tending to overestimate the number of factors needed in the presence of cross-correlated idiosyncratic components in the data.

We used criteria proposed by Bai and Ng (2002) and Amengual and Watson (2007) to

[9]See Appendix 7 for the details of information criteria used in this study.

determine the number of dynamic factors, q, for the given static number of factors and the number of lags. The estimated different criteria suggest a large range of number static factors (between 6-18) and the number of dynamic factors is in the interval 3-8. We choose the simple average of static factors, $r = 11$. Given the first eleven estimated factors and the number of lags determined BIC (1 lag), we found 4 dynamic factor using the correlation matrix of residuals (parameters $\delta = 0.1$ and $g = 1$). We preferred the model with $r = 11$ and $q = 4$ as our baseline; however, results for different number of factors are available in the section 5.

4.2 Evaluating empirical factors

Since the estimated latent factors are completely statistical phenomena by construction, an observable series could not be an exact factor in the mathematical sense. However, it can be a linear combination of the latent factors that matches the variation of the latent factors very closely. Nevertheless, it is useful to examine to what extent observable economic variables span the same information of the unobserved factors, to explain their economic meaning. Therefore, we constructed some statistics[10] developed by Bai and Ng (2006) to compare observable economic variables with unobserved factors, to assess how the observed variables are close (equal) to estimated factors.

Table 1: Evaluating latent factors and observed factors

	A(j)	*M(j)*	*R-square [interval]*	*NS(j)*	*canonical corr [interval]*
Federal Funds Rate	0.243	5.085	0.919 [0.890, 0.949]	0.088	0.701 [0.606, 0.796]
U.S. Real GDP	0.421	9.136	0.846 [0.793, 0.900]	0.181	0.924 [0.896, 0.952]
OECD Real GDP	0.617	8.444	0.802 [0.734, 0.869]	0.247	0.267 [0.124, 0.411]
U.S. Inflation	0.542	15.955	0.682 [0.582, 0.781]	0.467	0.883 [0.841, 0.925]
Oil Prices	0.636	16.929	0.525 [0.395, 0.655]	0.905	0.372 [0.227, 0.517]
Standard and Poor's Index	0.664	25.915	0.380 [0.235, 0.525]	1.633	0.042 [-0.032, 0.117]
Can/U.S. Exchange Rate	0.86	26.929	0.206 [0.070, 0.343]	3.849	0.474 [0.336, 0.611]

Note: NS(j) is simply the noise-to-signal ratio, A(j), M(j) and R-square are defined in Appendix 7. The interval of R-square are the lower and upper 95 per cent confidence interval, averaged over 1000 replications

Table 1 shows the results of testing following selected observable variables: U.S. and OECD economic activity measure, U.S. CPI, U.S. federal funds rate, Can/US nominal exchange rate, and global oil prices. The estimated statistics shows that the U.S. federal funds rate has the first highest R^2 and the lowest $NS(j)$, suggesting a strong relation with the latent factors. In addition, U.S. and OECD economic activity bears a strong relation with

[10] These statistics are described in detail in the Appendix 7.

common factors. Hence the evidence supports the notion that U.S. economic activity and federal fund rates can be described as strong potential candidates to a primitive shock that might drive common factors.

4.3 Model fit and R-squared

Figure 1 displays the R^2 of the regressions of the 260 individual time series from the panel data set. These R^2 are plotted as bar charts with one chart for each variable. The series are grouped by categories: U.S. related variables, real GDP, CPI, short-term interest rate and real exchange rate for the non-U.S. countries, and each category is divided in two sub-categories: developed countries (left side of red dash line) and developing countries (right side of red dash line). The common component in our model accounts for 80% of the total fluctuations, when averaging common variances across all 260 considered variables.

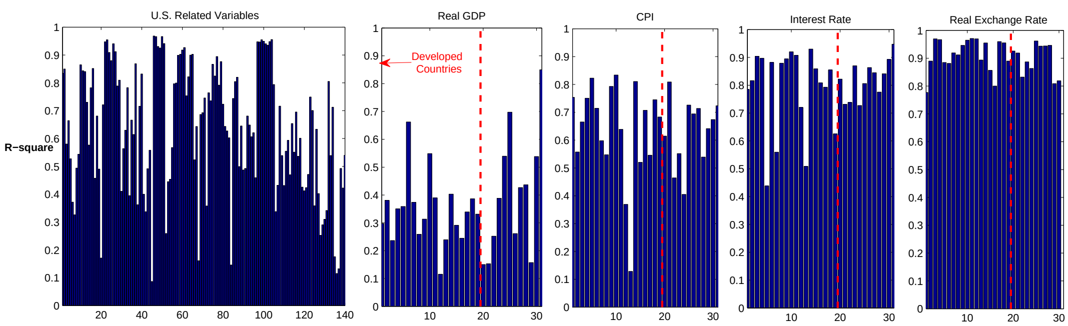

Figure 1: R^2 of Individual time series against estimated common factors.

Table 2: Grouped R-square of main macro variables

	Real GDP	*CPI*	*Interest rate*	*Real FX*
Regions				
N.Ame	0.76	0.72	0.91	0.88
L.Ame	0.30	0.75	0.63	0.87
Eu	0.39	0.72	0.88	0.94
Asia	0.29	0.49	0.77	0.9
Aust	0.36	0.62	0.72	0.89
Others	0.35	0.52	0.78	0.84
Economic Level				
Developed	0.41	0.69	0.86	0.92
Developing	0.29	0.55	0.71	0.89

Eleven estimated common factors account for 41% of the variance of real GDP in developed countries and 29% in developing countries; 69% of CPI in developed countries and 55% in developing countries; 86% of variance of short-term interest rate in developed countries and 71% of developing countries; and a considerable proportion of real exchange rate (about 90%) in developed and developing countries. The common factors can explain a significant change of financial variables, like interest rate and exchange rate. On the other hand, idiosyncratic (domestic) shocks play a larger role in real GDP, in particular in developing countries. Another important observation arises from Table 2 that variance of economics variables in developed countries due to global common factors are relatively larger, which could be associated with higher financial integration into the global market.

4.4 Forecast error variance decomposition:

In order to evaluate the role of U.S. monetary policy shocks, we decompose the variance of real GDP, CPI, short-term interest rate and real exchange rate into contributions due to selected variables[11] used in identification of six regional groups and two economic level groups[12].

Specifically, in a forecast error variance decomposition, we calculate what fraction of the total forecast error variance for a particular variable is due to a U.S. monetary policy shock for a given forecast horizon (k). The percentage of the forecast error variance caused by U.S. monetary policy shock for the group of key macroeconomic variables is summarised in Table 3 .

In the short-term, the U.S. monetary policy shock has almost no effect on real GDP and aggregate prices for North America but, after three years, the shock explains about 23% of real GDP and prices. This aligns with the finding of Forni and Gambetti (2010) that uses only U.S. related variables. Its impact on other regional groups are quite heterogeneous in the short run, ranging from 14% for the Others and up to 53% for Asia. Over the medium-term, this effect increases for almost all groups. Moving to the economic level groups, the U.S. monetary policy have a more prominent role in explaining business cycles in developing countries. It accounts for 60% in developing countries, which is about twice as much as in developed countries.

As we can see from Table 3, the contribution of the policy shock to prices after three years accounts for in the range of 20 to 28 percent apart from in Latin America (52 %).

[11] The variables used in identification schemes are U.S. real GDP, U.S. CPI, fed funds rates and Can/U.S. real exchange rate.

[12] The weighted average of each country within a group (region or economy level) is calculated using annual real gross domestic product (at purchasing power parity) at constant prices in international dollar from Penn World Table for 2006. The full set of results for all countries in our panel is available upon request.

Table 3: Forecast error variance decomposition for different groups

	k=1	*k=4*	*k=8*	*k=12*
Regions:	**Real GDP**			
N. Ame	0.00	0.16	0.22	0.23
L. Ame	0.49	0.39	0.45	0.45
Europe	0.25	0.29	0.35	0.37
Asia	0.53	0.61	0.56	0.55
Australasia	0.43	0.36	0.44	0.45
Others	0.14	0.38	0.46	0.45
Economic Level:				
Developed	0.18	0.25	0.3	0.31
Developing	0.52	0.66	0.61	0.6
Regions:	**CPI**			
N. Ame	0.00	0.15	0.21	0.23
L. Ame	0.37	0.37	0.47	0.52
Europe	0.08	0.17	0.17	0.21
Asia	0.13	0.15	0.23	0.26
Australasia	0.3	0.26	0.28	0.28
Others	0.15	0.27	0.25	0.26
Economic Level:				
Developed	0.08	0.16	0.2	0.24
Developing	0.12	0.19	0.27	0.29
Regions:	**Short Term Interest Rate**			
N. Ame	0.87	0.86	0.85	0.83
L. Ame	0.17	0.15	0.25	0.27
Europe	0.34	0.38	0.39	0.43
Asia	0.17	0.18	0.26	0.34
Australasia	0.24	0.21	0.21	0.31
Others	0.09	0.23	0.21	0.23
Economic Level:				
Developed	0.51	0.53	0.53	0.54
Developing	0.22	0.23	0.34	0.42
Regions:	**Real Exchange Rate**			
N. Ame	0.14	0.53	0.48	0.42
L. Ame	0.21	0.2	0.43	0.55
Europe	0.49	0.6	0.55	0.53
Asia	0.03	0.19	0.28	0.34
Australasia	0.21	0.4	0.49	0.43
Others	0.08	0.51	0.44	0.37
Economic Level:				
Developed	0.33	0.46	0.48	0.46
Developing	0.06	0.24	0.3	0.38

Notes: k is quarters after the US monetary policy shock on the columns.

Similar to real GDP, the U.S. monetary policy has a larger impact on developing countries' price level (29%) than developed countries' (24%).

The U.S. monetary policy shock explains about 50 per cent and 46 per cent of the fluctuations after one year in developed countries' short-term interest rate and real exchange rate, respectively, which is almost twice as high as fluctuations in developing countries.

Overall, the empirical results confirm a substantial role for U.S. monetary policy in affecting the dynamics key macro variables of the U.S. itself and the rest of the world, relative to other external U.S. shocks. However, note that the policy impact differs across regions and across countries. The policy impact is more significant on real output and prices in developing countries, and more significant on short-term interest and real exchange rate in developed countries.

4.5 Impulse responses to the contractionary U.S. monetary policy

Impulse responses to the U.S. monetary policy shock are presented in this section. A shock is defined as an increase in the federal funds rate by 50 basis points. We show the impulse responses of real GDP, CPI, short-term interest rate and real exchange rate for regional groups in Figures 2 and for income level groups in Figures 3. The regional impulse responses are calculated by the weighted average of individual country impulse response functions according to real GDP[13]. Each figure contains the impulse responses, together with coloured fan charts for 90, 80 and 68 percentiles computed by standard bootstrapping[14].

4.5.1 Real economic activity

Regarding real GDP responses, the contractionary U.S. monetary policy leads to analogous impulses response functions for all regions. Real GDP falls significantly, with a typical inverted hump-shaped response. It reaches the maximal reduction between 4-6 quarters. The largest contractionary effects on real activity are observed in Latin America and the Others group.

Overall, U.S. monetary policy matters when it comes to explaining fluctuations in other countries' economic activity. An increase in the U.S. federal funds rates generates larger contractions in developing countries.

[13]The figures for individual countries impulse response functions to the shock are available upon request.

[14]Standard confidence bands are obtained using the following steps: i) estimate model and take residuals, ii) draw residuals randomly with reintroduction from model residuals to generate new factors and a new data set , iii) compute new impulse response functions using generated data, iv) distribution of impulse-response functions is obtained by repeating drawing and estimation.

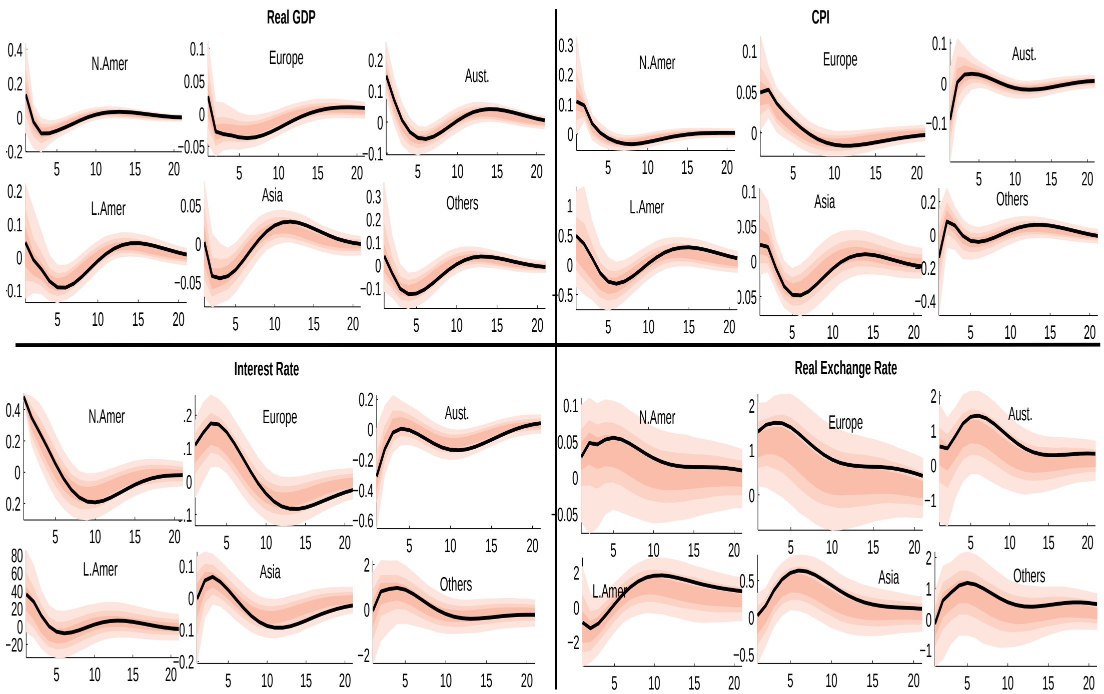

Figure 2: Impulse responses functions to 50 basis points increase in U.S. federal funds rate on regional groups

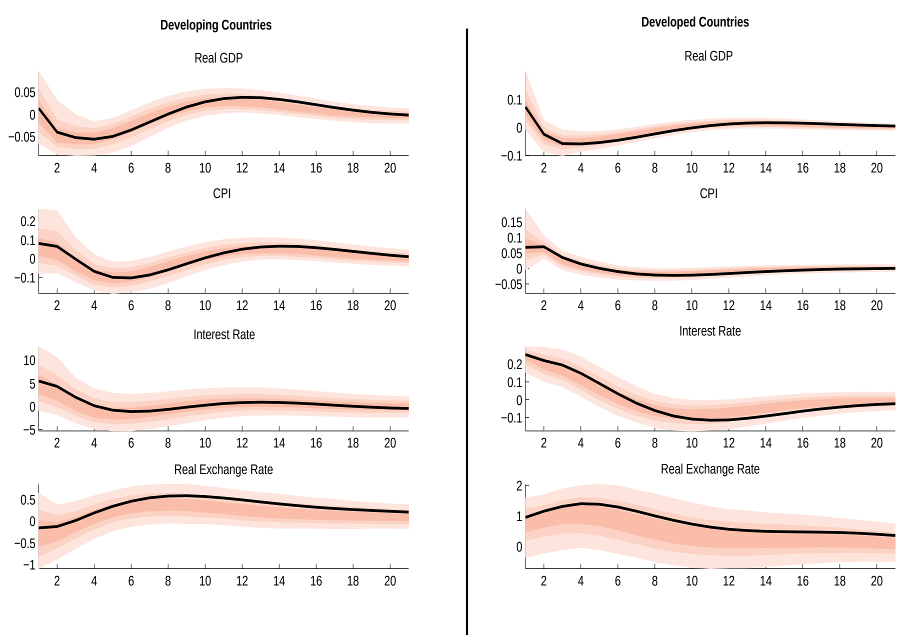

Figure 3: Impulse responses functions to 50 basis points increase in U.S. federal funds rate on income level groups

4.5.2 Consumer price index

The contractionary U.S. monetary shock declines U.S. prices and prices in all regional groups, which is consistent with standard theoretical models of monetary policy. Regional groups have a negative response with a little delay and reach their dip between one-and-a-half and two-and-a-half year horizons. On the other hand, prices in Australasia oddly decline immediately and then start to increase and decrease again[15].

Overall, contractionary U.S. monetary policy leads to a significant decline in prices in both developed and developing countries, but the decline in developing countries' prices is more pronounced and reaches the maximal point earlier.

4.5.3 Short-term interest rate

The increase in the U.S. interest rate leads to an increase in the other countries' interest rate since the U.S. is a large, open economy that impacts other countries that are integrated into global capital market to some extent. In line with economic theory, short-term interest rates in all regions except Australasia are found to respond statistically significantly and negatively to the contractionary U.S. monetary policy shock[16].

The response of developing countries' interest rates is an average of 400 basis points; this is larger than developed countries, which average 25 basis points. When we compare country-level responses, we note that, except New Zealand, the responses are all in same direction (positive), but the magnitudes differ by countries. This may be related to cross-country structural differences; such as the degree of integration into the world capital market, exchange rate regimes etc. For instance, Latin American countries have strong trade and financial linkages to the United States. Hence, the shape of response of Latin America displays a similar pattern to the U.S. interest rate path with the interest rate reacting immediately and then starting to reduce. The reaction of this region is also the largest in our groups[17].

4.5.4 Real exchange rate

Our estimations support the findings in the literature by suggesting an appreciation of the U.S. dollar following contractionary U.S. monetary policy shock. However, the real exchange rate in Latin America depreciates insignificantly in first three quarters following the shock and then starts to appreciate. Moving to groups according to economic levels, real exchange

[15] This interesting response is only due to the response of Australia in this regional group, while New Zealand's response is similar to other countries on our sample.

[16] In fact, Australia's interest rate is positive. However, since New Zealand's response is insignificant and negative for a long time, on aggregate, the response for that region seems to be a negative reaction. New Zealand might reduce their interest rate to protect their economy from the contractionary effect of U.S. monetary policy, so we can observe an increase in real GDP.

[17] Even if we omit hyperinflation country Argentina which has extremely large responses from Latin America region, the response of short-term interest rate still remains the largest.

rate appreciates in developed and developing countries. Insignificant depreciation of developing countries was observed in the initial periods due to the Latin American countries' response.

Differentiation in real exchange rate's responses can potentially be explained by relative interest rates between U.S. and non-US countries. The initial real exchange rate depreciation in developing countries might be a consequence of capital outflow generated by relatively high non-US interest rates, since contractionary U.S. monetary policy shock generates a larger increase in developing countries' interest rate.

Our impulse response analysis first indicates the importance of international linkages: shocks to U.S. monetary policy transmit internationally to the rest of the world. Secondly, we find significant cross-country heterogeneity in responses to the same external shock, though responses in developing countries tend to be larger. Shocks to U.S. federal funds rate leads quantitative difference in interest rate responses which generate heterogeneity in propagation of U.S. monetary policy to other countries' real exchange rates, prices and economic activities responses.

4.6 What drives the difference in cross-country responses?

Both the existence of cross-country heterogeneity and co-movements in responses to U.S. monetary policies motivate the question guiding this section[18]. The theoretical literature suggests some possible reasons why the effect of a foreign monetary policy might vary across countries in the open economy context. These include difference in exchange rate regimes, degree of exchange rate pass-through to import prices (ERPT), degree of central bank independence, degree of financial integration and trade costs.

In order to examine the role of country-specific characteristics in heterogeneity of propagation of U.S. monetary policy across countries, we regress the country level responses on the country-specific characteristics. Since there is a low ratio of number observations to number variables and correlated predictors, the least angle regression (LARS) method proposed by Efron et al. (2004), is applied to the following cross-country equation[19]:

$$Y_i = \varphi X_i + \xi \tag{8}$$

[18]Heterogeneity suggests quantitative and qualitative asymmetric reactions to the same policy shock.

[19]This method is a good linear model to predict a response variable, y, on the basis of correlated predictors, x_i. This regression algorithm also avoids over-fitting and obtains parsimonious and interpretable models, especially when the number of parameters exceeds the number of observations, and accounts for variables grouping in a high-dimensional data set. See Efron et al. (2004) for details of LARS; see Hesterberg et al. (2008) for a review and comparison with other methods.

where Y_i is defined as the estimated cumulative responses of country i at horizons 1, 2, 4 and 8 quarters that computed from the estimated DFM. ξ is an error term. The vector X_i includes the probability of observing the individual exchange regime over the sample, degree of exchange rate pass-through into import prices, a measure of central bank independence, log distance and average tariffs as proxies for trade cost. X_i are computed as sample period averages over the period where the data is available[20]. We present the results together in Table 4.

4.6.1 Role of exchange rate regimes

Our analysis covers the 1979-2013 period which includes numerous regime changes for many countries. So the question is: how do international transmission mechanisms vary according to the exchange rate regimes or can shifts in exchange rate regimes explain cross-country heterogeneity in responses to the same U.S. contractionary monetary policy?

One would expect the countries that have fixed exchange rate regimes (*fixers*) to raise interest rates in response to a contractionary U.S. monetary shock, since an interest rate differential with the U.S. would be inconsistent with a fixed exchange rate. The countries that have floating exchange rate regimes, on the other hand, could absorb part of the effect on the domestic interest rate by allowing their currency to depreciate against the U.S. dollar.

As can be seen from Table 4, estimates for fixed exchange rate regimes are statistically significant at the short horizon for interest rate and real exchange rate; and at the medium horizon for real GDP. This suggests that interest rates in countries with fixed exchange rate regimes react to the U.S. monetary policy shock; hence it affects real GDP.

[20] The regression estimation potentially suffers from time variation and measurement errors in predictors. There are numerous studies in the literature that discuss how central bank independence and trade cost can be evaluated by the time. For example, Crowe and Meade (2007) find significant change in CBI for developing countries.

Table 4: LARS results of IRFs on country characteristics

	k=1				k=2				k=4				k=8			
	model 1	model 2	model 3	model 4	model 1	model 2	model 3	model 4	model 1	model 2	model 3	model 4	model 1	model 2	model 3	model 4
GDP																
Distance	0.008**	0.009**	0.010**	0.004	-0.003	-0.003	-0.002	0.003	-0.008*	-0.009*	-0.007*	-0.004**	-0.006*	-0.006*	-0.005*	-0.0031**
	0.004	0.005	0.006	0.008	0.002	0.003	0.003	0.004	0.002	0.002	0.002	0.002	0.001	0.001	0.001	0.0018
Tariff	-0.018	-0.012	-0.008	-0.013	-0.006	0.004	0.008	0.012	0.007	0.018*	0.027*	0.029*	0.009	0.011**	0.014*	0.016*
	0.019	0.021	0.024	0.024	0.011	0.011	0.012	0.012	0.009	0.009	0.009	0.008	0.005	0.006	0.006	0.006
Fixed FX		-0.195	-0.172	-0.122		-0.197*	-0.175**	-0.222*		-0.214*	-0.164*	-0.194*		-0.044	-0.022	-0.039
		0.172	0.183	0.188		0.09	0.096	0.092		0.068	0.066	0.064		0.047	0.048	0.049
Floating		-0.026	-0.033	0.004		0.031	0.038	0.016		0.013	0.029	0.016		0.001	0.008	0.001
		0.118	0.055	0.123		0.062	0.064	0.06		0.047	0.044	0.042		0.032	0.032	0.032
EU		-0.028	-0.018	-0.08		0.009	0.004	0.049		0.019	0.009	0.037		-0.002	-0.006	0.01
		0.053	0.122	0.123		0.028	0.029	0.034		0.021	0.02	0.024		0.015	0.015	0.018
ERPT			-0.038	-0.076			-0.035	0			-0.082*	-0.060**			-0.037	-0.024
			0.094	0.123			0.049	0.049			0.033	0.034			0.025	0.026
CBI				0.137				-0.128*				-0.080**				-0.046
				0.123				0.061				0.042				0.032
R-square	0.027	0.077	0.083	0.129	0.013	0.208	0.224	0.35	0.017	0.36	0.489	0.558	0.085	0.118	0.192	0.259
CPI																
Distance	0.002	0.001	-0.005	0.022**	0.006	0.006	0.010*	-0.001	0.003	0	0.005	0.001	-0.001	-0.006	-0.007	0.011
	0.008	0.01	0.011	0.012	0.004	0.005	0.005	0.006	0.004	0.005	0.004	0.006	0.007	0.008	0.009	0.012
Tariff	-0.019	-0.01	-0.037	-0.017	-0.013	-0.013	0.006	-0.003	-0.028	-0.026	-0.002	-0.005	-0.039	-0.032	-0.033	-0.02
	0.037	0.042	0.045	0.039	0.017	0.02	0.02	0.018	0.018	0.02	0.019	0.019	0.032	0.035	0.039	0.037
Fixed FX		-0.15	-0.309	-0.545		-0.008	0.101	0.197		0.032	0.172	0.209		0.063	0.057	-0.097
		0.339	0.347	0.304		0.159	0.154	0.139		0.16	0.144	0.149		0.28	0.3	0.287
Floating		-0.03	-0.082	-0.189		-0.024	0.011	0.055		0.056	0.102	0.118		0.124	0.122	0.052
		0.234	0.231	0.199		0.109	0.102	0.091		0.11	0.096	0.097		0.193	0.199	0.187
EU		0.023	0.055	0.279*		0.001	-0.022	-0.113*		0.042	0.013	-0.022		0.09	0.091	0.237*
		0.105	0.105	0.113		0.049	0.046	0.052		0.05	0.044	0.055		0.087	0.09	0.107
ERPT			0.264	0.442*			-0.181	-0.254*			-0.233*	-0.260*			0.01	0.126
			0.177	0.161			0.079	0.074			0.074	0.079			0.153	0.151
CBI				-0.643*				0.263*				0.192**				-0.420*
				0.201				0.092				0.098				0.189
R-square	0.008	0.021	0.103	0.38	0.014	0.016	0.194	0.405	0.082	0.11	0.371	0.398	0.045	0.091	0.09	0.251
Short-term interest rate																
Distance	-0.056	-0.017	-0.005	0.268	-0.008	0.043	0.01	-0.115	0.056	0.015	0.005	-0.156	0.038	-0.058	-0.007	0.046
	0.189	0.241	0.011	0.272	0.074	0.092	0.005	0.071	0.122	0.154	0.004	0.182	0.124	0.154	0.009	0.225
Tariff	0.645	0.744	-0.037	0.053	0.501	0.495	0.006	0.009	-0.52	-0.595	-0.002	-0.171	-0.874	-0.904	-0.033	-0.48
	0.882	0.998	0.045	0.857	0.343	0.381	0.02	0.224	0.568	0.64	0.019	0.572	0.58	0.64	0.039	0.707
Fixed FX		-3.601	-0.309	-14.709*		-1.77	0.101	3.973*		3.248	0.172	9.994*		4.27	0.057	6.578
		7.985	0.347	6.702		3.051	0.154	1.751		5.119	0.144	4.472		5.119	0.3	5.527
Floating		-1.435	-0.082	-5.658		-1.308	0.011	1.248		1.261	0.102	3.824		2.57	0.122	3.316
		5.509	0.231	4.381		2.105	0.102	1.145		3.532	0.096	2.923		3.532	0.199	3.613
EU		-0.581	0.055	5.160*		-0.846	-0.022	-2.087*		0.68	0.013	-2.794**		1.597	0.091	1.209
		2.475	0.105	2.494		0.946	0.046	0.652		1.587	0.044	1.664		1.587	0.09	2.057
ERPT			0.264	14.220*			-0.181**	-3.666*			-0.233*	-8.651*			0.01	-3.938
			0.177	3.538			0.079	0.924			0.074	2.361			0.153	2.918
CBI				-12.686*				4.879*				7.658*				-0.307
				4.421				1.155				2.95				3.646

Continuation of Table 4

	k=1				k=2				k=4				k=8			
	model 1	model 2	model 3	model 4	model 1	model 2	model 3	model 4	model 1	model 2	model 3	model 4	model 1	model 2	model 3	model 4
R-square	0.018	0.027	0.103	0.463	0.065	0.103	0.194	0.523	0.0286	0.048	0.371	0.43	0.07	0.124	0.09	0.199
Real exchange rate																
Distance	0.082**	0.036	0.06	0.158*	0.104*	0.05	0.074**	0.122*	0.119*	0.074*	0.094*	0.114*	0.098*	0.076*	0.069*	0.075*
	0.046	0.046	0.048	0.06	0.042	0.038	0.04	0.053	0.028	0.025	0.026	0.035	0.015	0.016	0.017	0.023
Tariff	-0.315	-0.047	0.064	0.14	-0.245	0.022	0.133	0.171	-0.151	0.036	0.127	0.143	-0.031	0.046	0.011	0.016
	0.214	0.189	0.204	0.188	0.194	0.159	0.168	0.168	0.132	0.105	0.107	0.11	0.071	0.066	0.071	0.074
Fixed FX		-3.946*	-3.298*	-4.170*		-3.675*	-3.023*	-3.447*		-2.404*	-1.873*	-2.052*		-0.859	-1.060**	-1.116**
		1.514	1.566	1.469		1.271	1.293	1.312		0.838	0.826	0.856		0.527	0.549	0.576
Floating		-0.521	-0.308	-0.701		-0.072	0.142	-0.049		0.571	0.746	0.665		0.362	0.295	0.27
		1.045	1.04	0.96		0.877	0.859	0.857		0.578	0.549	0.56		0.363	0.365	0.376
EU		1.031*	0.899**	1.725*		1.125*	0.992*	1.394*		0.837*	0.729*	0.898*		0.404*	0.445*	0.498*
		0.469	0.472	0.547		0.394	0.39	0.488		0.26	0.249	0.319		0.163	0.165	0.214
ERPT			-1.077	-0.421			-1.186*	-0.991**			-0.883*	-0.748			0.335	0.377
			0.8	0.775			0.523	0.557			0.422	0.452			0.28	0.304
CBI				-2.371*				-1.154				-0.487				-0.151
				0.969				0.865				0.565				0.38
R-square	0.07	0.438	0.478	0.586	0.044	0.501	0.551	0.614	0.021	0.522	0.596	0.608	0	0.281	0.322	0.326

We have categorised countries according to regimes to see how responses changes according to shifts in exchange rate regimes. We divide countries into three groups: *i*) European Union countries, *ii*) floating countries outside the EU and *iii*) non-floating countries outside the EU. If the floating exchange rate regime occurs more than 50 percent over the sample for a country, then we assume that it belongs to the "*floaters*" category on average. Otherwise, it belongs to the "*non-floaters*" group.

As can be seen from Figure 4, the response of real GDP, prices and interest rate are smaller but response of real exchange rate is larger in *floaters*[21] .They allow their currency to depreciate against the U.S. dollar to absorb the contractionary effect of U.S. monetary policy shock on the domestic interest rate partially.

Overall, our empirical results show that we cannot reject transmission of U.S. monetary policy shocks to non-US countries, even for countries with floating exchange rate regime. However, adopting a floating exchange regime helps to insulate the economy from foreign monetary spillovers where countries with a less flexible regime adjust their interest rate more quickly and hence experience larger real impact on local economies.

4.6.2 Role of currency of price setting

One of the central issues in open macroeconomics is currency of price setting of firms. The literature uses "producer currency pricing" (PCP) when firms set export prices in their currencies and "local currency pricing" (LCP) when they set export prices in their importer's currencies. An extensive literature has investigated the policy implications of different price setting behavious when prices are sticky in the short-run[22].

A currency choice for invoicing matters since it plays a key role in how international shocks are transmitted across countries and how monetary policy should be designed optimally in open economies. It affects the extent of impact of exchange rate movements on international prices, exchange rate pass-through (ERPT), and so demand switches across countries. In the case of PCP, monetary shocks cause fluctuations in exchange rate and exchange rate fluctuations are transmitted to the consumer prices (high pass-through). It then modifies the relative prices of domestic and imported goods. For example, an appreciation in the exchange rate makes import goods cheaper in terms of domestic currency and leads to switch the demand towards import goods (expenditure-switching effect). This is not the case under LCP strategy, because relative prices of domestic and imported goods remain unchanged by movements in exchange rate, since prices are denominated in the importer's currency.

[21]Excluding Brazil from the sample reduces the response of interest rate to 25 basis points in floaters, but it is still higher than non-floaters.

[22]Obstfeld and Rogoff (1995), Devereux et al. (2004), Corsetti and Pesenti (2004), Goldberg and Tille (2008) are examples.

Difference in price setting behaviour is a possible source of variation in U.S. monetary policy shock's transmission across countries. Pricing-setting in export market is complex and there exist numerous theoretical and empirical papers that examine the currency choice of firms[23]. However data of currency of price setting on the countries in our sample is not available.

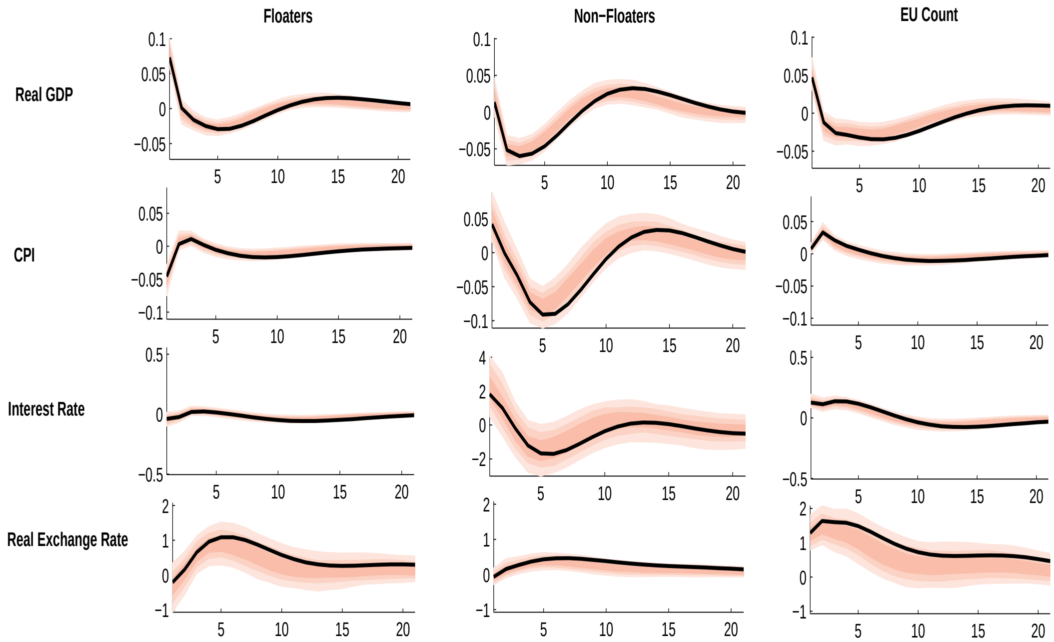

Figure 4: Impulse responses functions to 50 basis points increase in U.S. federal funds rate on groups according to adopted Exchange Rate Regime

Evidence in the empirical literature regarding currency choice of exports is mixed. For example, Gopinath et al. (2010) find substantial difference in the pass-through of average goods priced in U.S. dollars (25%) versus in non-dollars (95%) across countries. Goldberg and Verboven (2005) find high degrees of pass-through suggesting that pricing in the currency of the producer is a common practice for automakers selling in five European countries. Conversely, Campa and Goldberg (2005) find evidence of partial exchange rate pass-through in the short-run in the import prices of 23 OECD countries and so reject both hypotheses that prices are set in PCP or LCP.

Eventually, the issue of currency choice becomes an empirical one and indirect evidence can be drawn from the degree of exchange rate pass-through to import prices to use as a proxy. Following Campa and Goldberg (2005), we calculate exchange rate pass-through into

[23]See Giovannini (1988), Bacchetta and van Wincoop (2005), Devereux et al. (2004), Campa and Goldberg (2005), Goldberg and Tille (2008) and Gopinath et al. (2010).

import prices using micro-foundations of pricing behaviour by exporters. In our specification a complete pass-through into import prices of goods represents pricing in the producer's currency and zero per cent pass-through represents pricing in the local currency[24].

The estimate of ERPT elasticity can be seen in Table 4. We find that estimates for ERPT are statistically significant at the short horizon for interest rate and real exchange rate; and at the medium horizon for real GDP[25]. We have also split countries in our sample into three different groups according to estimated ERPT: *i)* countries with LCP (low pass-through), *ii)* countries with PCP (high pass-through) and *iii)* countries with neither LCP nor PCP (partial pass-through)[26]. We compute impulse responses for these three different groups to examine the role of currency of price setting, as shown in Figure 5.

The reaction of countries with PCP to the contractionary monetary policy shocks is larger. The response of the CPI level is relatively smaller in countries with LCP, as expected, since there is a lower pass-through to local prices in the LCP case. Hence prices, as well as relative prices to U.S. prices, are unchanged in the LCP case, which weakens the traditional expenditure switching channel of nominal exchange rate and lessens variation in the local production. Because LCP acts limit spillovers to local conditions, central banks react less to the monetary shocks from abroad.

4.6.3 Role of central bank independence

Greater monetary independence potentially insulates the domestic economy from any political cycle and external foreign shocks by allowing policy makers to stabilise the economy through monetary policy without being restricted by foreign economies' macroeconomic outcomes. A central bank with a high degree independence renders the use of monetary policy tools more efficient in achieving its domestic targets.

Several measures of central bank independence have been proposed in the literature (for different measures and their discussions see Cukierman et al. (1992) (henceforth CWN), Alesina and Summers (1993), Berger et al. (2001), Crowe and Meade (2007)).

In this study, we use the overall measure constructed by Crowe and Meade (2007) as a proxy for central bank independence. They compute an updated index of CWN for a larger

[24]See section 7 for detailed specification and estimation of short-run and long-run exchange rate pass-through for countries in our sample.

[25]However, the significance of the currency choice vanishes after 2 years. This is consistent with the theoretical assumption that rigid prices become flexible (adjust) in the long-run and the difference in exchange rate pass-through of different currency pricing choices vanishes.

[26]We used the following criterion for selection: if a country's 95% confidence interval of short-run exchange rate elasticity contains zero (one), then we assume that it belongs to countries LCP (PCP); if it does not contain zero or one, then it belongs to countries with neither LCP or PCP.

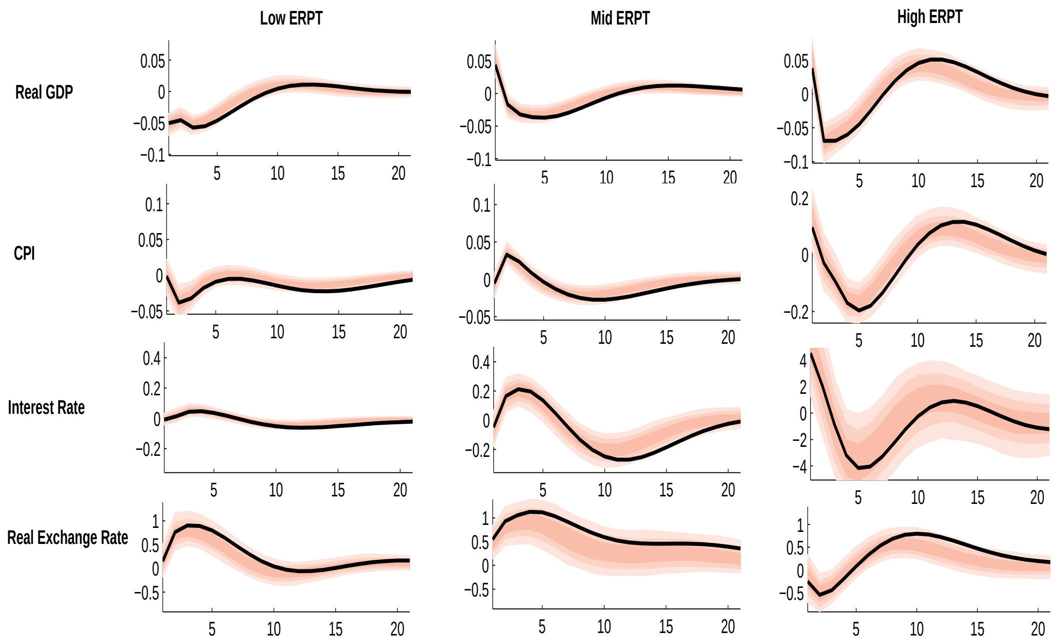

Figure 5: Impulse responses functions to 50 basis points increase in U.S. federal funds rate on groups according to degree of ERPT

number of countries using 2003 data from the IMF's database of central bank laws. Although overall independence index for central banks varies by country, the average for developed and developing countries seem very close[27].

As can be seen from Table 4, estimates for central bank independence are statistically significant for almost all macro variables. We split countries into two categories: *i)* countries with low CBI, and *ii)* countries with high CBI and compute impulse response as shown in Figure 6[28]. The response of real GDP for both groups appear very similar. However, the response of interest rate and prices are larger in countries that have low central bank independence. It seems that difference in monetary policy independence is another important country characteristics in explaining cross-country differences in particular interest rate heterogeneity.

[27]We ignore time-varying change in independence of central banks for the present. Crowe and Meade (2007) find evidence that shows increasing independence for central banks across all countries. They find statistically significant increase in index and sub-components for developing and emerging countries since the 1980s.

[28]If a country's central bank independence is higher than 0.70 (very close to our sample median), then we assume that it has high central bank independence. If it is less than 0.70, then it has low central bank independence.

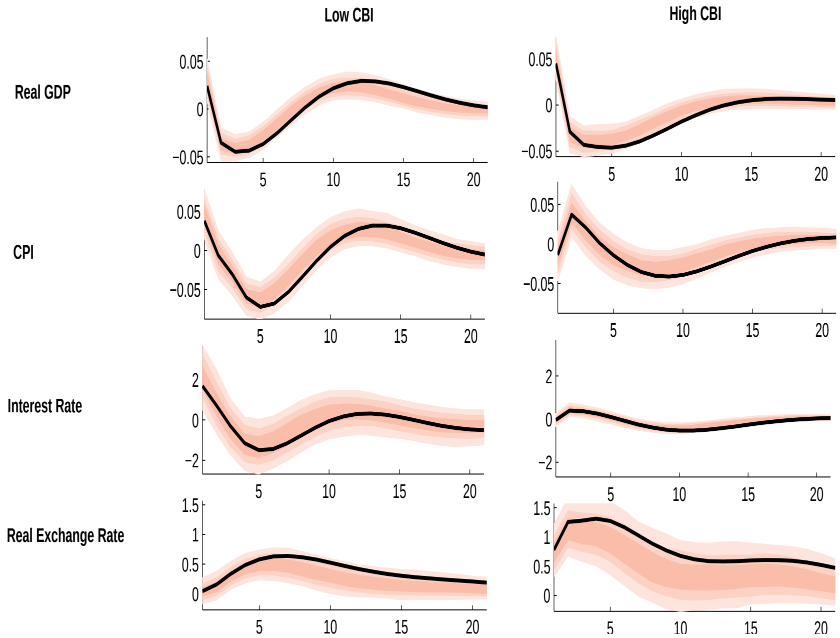

Figure 6: Impulse responses functions to 50 basis points increase in U.S. federal funds rate on groups according to degree of central bank independence

4.6.4 Role of distance from the United States

Open economies interact with the rest of the world directly through exports and imports and hence trade is one of the main channels of propagation of shocks to other countries. Changes in monetary conditions affect bilateral trade cost and hence import prices. Shifts in relative prices lead to switching demand across countries. Difference in trade cost may be related to heterogeneous international transmission of shocks.

Distance to the United States is calculated using the latitudes and longitudes of the capital cities from Mayer and Zignago (2006). We calculate tariff estimates as a simple mean of the applied tariff for all traded goods by the World Bank. A log of geographical distance and average trade tariff are used as a proxy for trade cost[29].

As can be seen from Table 4, estimates for log distance are statistically significant for real GDP, CPI and real exchange rate but not for interest rate. However, this is not the case for trade tariffs, which could be due to limited heterogeneity in average tariffs data. We split countries into two categories: *i)* countries with low distance, and *ii)* countries with high distance and compute impulse responses for these groups, as shown in Figure 7[30]. Countries that are geographically closer to the United States have a larger response to contractionary

[29] We assume that the cost of bilateral trade increase sharply with the distance (and thus transportation cost) between trading partners; and diminishes with a shared language and adjacency corresponds.

[30] If a country's geographical distance is higher than the 6^{th} percentile, we assume that it has high distance. Otherwise, it has low distance.

monetary shocks from the U.S..

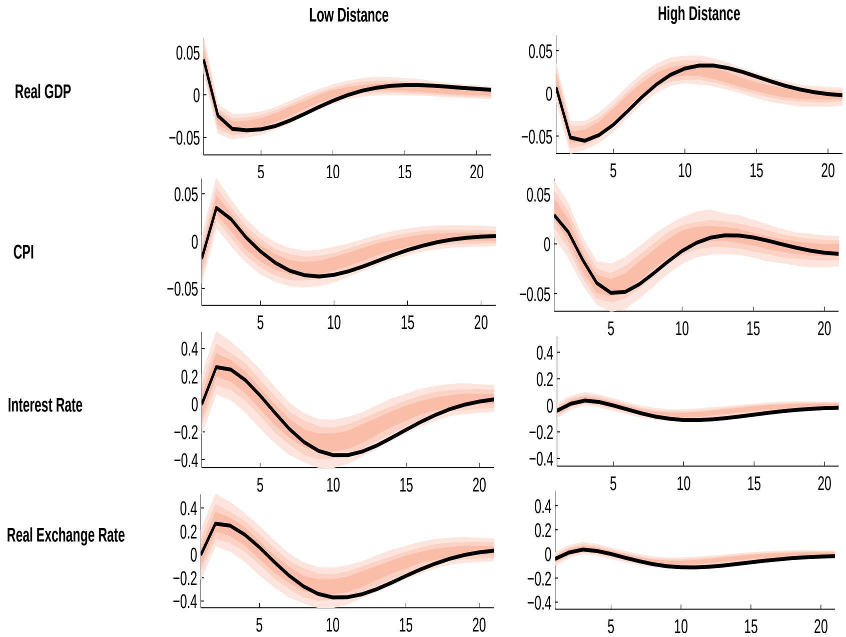

Figure 7: Impulse responses functions to 50 basis points increase in U.S. federal funds rate on groups according to to distance from United States

5 Robustness analysis

In this section, we examine the robustness of the results shown to changes in a number of dynamic and static factors, identification schemes and monetary policy measures. We also perform a structural estimation on an extended sample that covers the global financial crisis period to evaluate the impact of unconventional monetary policy.

5.1 Choice of number of factors

Different information criteria suggest a different number of factors. The number of static and dynamic factors was set to 11 and 4, respectively, by taking the simple average of popular criteria. We investigate the sensitivity of our results with respect to the number of dynamic and static factors as a robustness check. The impulse response functions of groups according to economy level for a different number of factors are reported[31]. We repeat analysis for

[31] The impulse responses are also calculated for all regional groups and individual countries are available upon request.

different a number of static factors, r, $r \in \{6, 9, 11, 13, 14, 18\}$ and number of dynamic factors, q, $q \in \{4, 5, 6, 7\}$.

Almost all models with different specifications deliver the same shape of the impulse response functions, which implies that they are qualitatively the same as shown in Figure 8 and 9. It was only in two cases (when $r = 6$ and $r = 9$) that the response of interest rates at the short horizon differ in sign and magnitude. It seems that less than 11 static factors are not informationally sufficient to capture common components for our large heterogeneous data set.

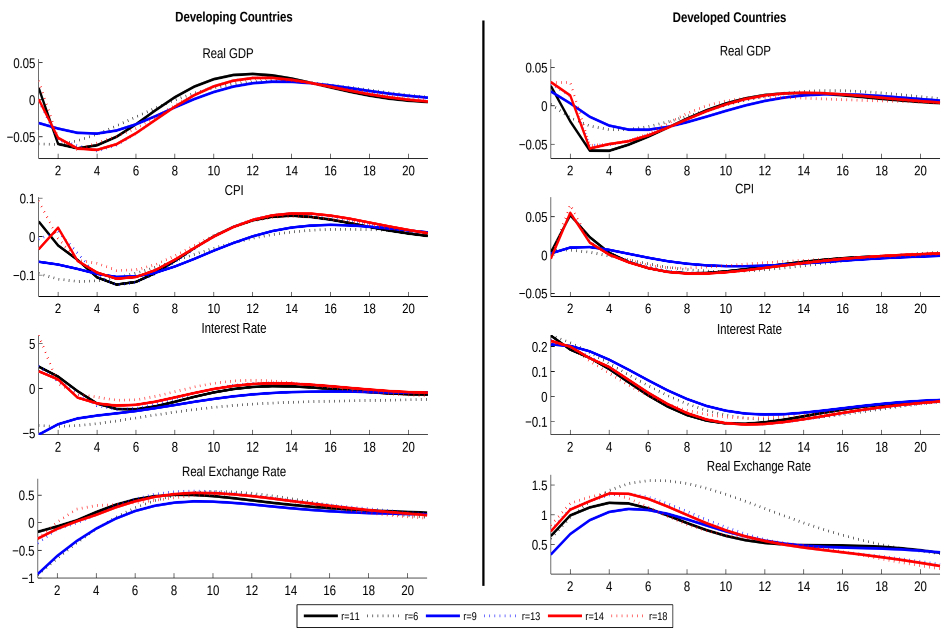

Figure 8: Impulse response functions to 50 basis points increase in U.S.federal funds rate for different number of static factors

5.2 An alternative identification method: recursive identification based on zero restrictions (Cholesky factorisation)

In our baseline model, we identify monetary policy shock by adopting a novel method that approaches exogenous shocks as external instrumental variables. Alternatively, we identify monetary policy shocks using the most diffused recursive identification scheme based on a recursive ordering of the variables[32]. The analyses are repeated for the new identification

[32] This simple identification scheme is criticised since it imposes zero short-run restrictions, which are too binding and do not necessarily rely on theoretical consideration. In the section 7, we present technical details of this novel identification scheme.

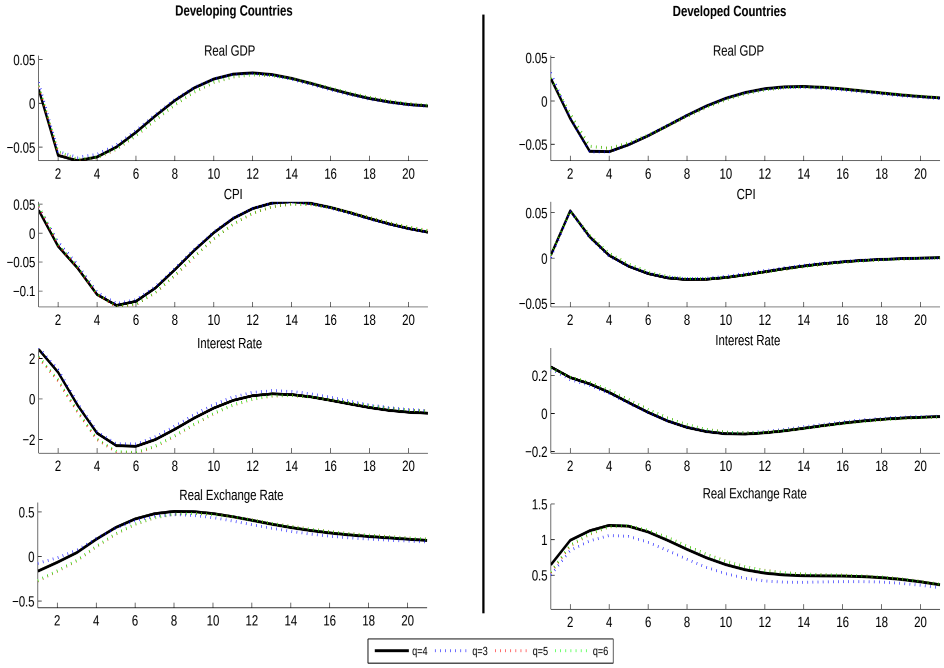

Figure 9: Impulse response functions to 50 basis points increase in U.S. federal funds rate for different number of dynamic factors

and the impulse responses are shown in Figure 10.

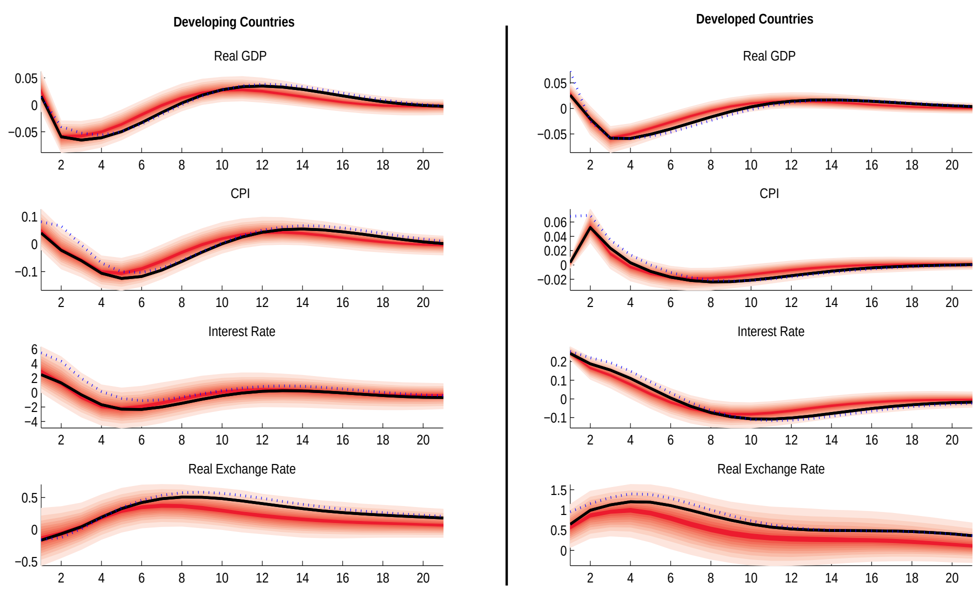

Figure 10: Impulse response functions to 50 basis points increase in U.S. federal funds rate for an alternative identification

The responses obtained from the recursive identification are similar to the responses and external instrument method remain in the confidence band. Responses of real GDP are quite similar; the responses of interest rate and real exchange rate are slightly larger but the responses of prices are smaller.

5.3 New monetary policy measure for zero lower bound period

We perform our estimation on different sub-samples to evaluate the consequences of the global financial crisis (GFC) and compare spillovers of unconventional monetary policy and traditional monetary policy. Since federal funds rates have been stuck at zero lower bound (ZLB) since late 2008, and the Federal Reserve applies unconventional monetary policy through large scale asset purchase and forward guidance, the federal funds rate is not suitable for use as a measure of monetary policy stance for the GFC period. We choose shadow rates as a proxy that was calculated by Wu and Xia (2016) as a new way to measure the monetary policy stance at ZLB based on movements in forward rates[33].

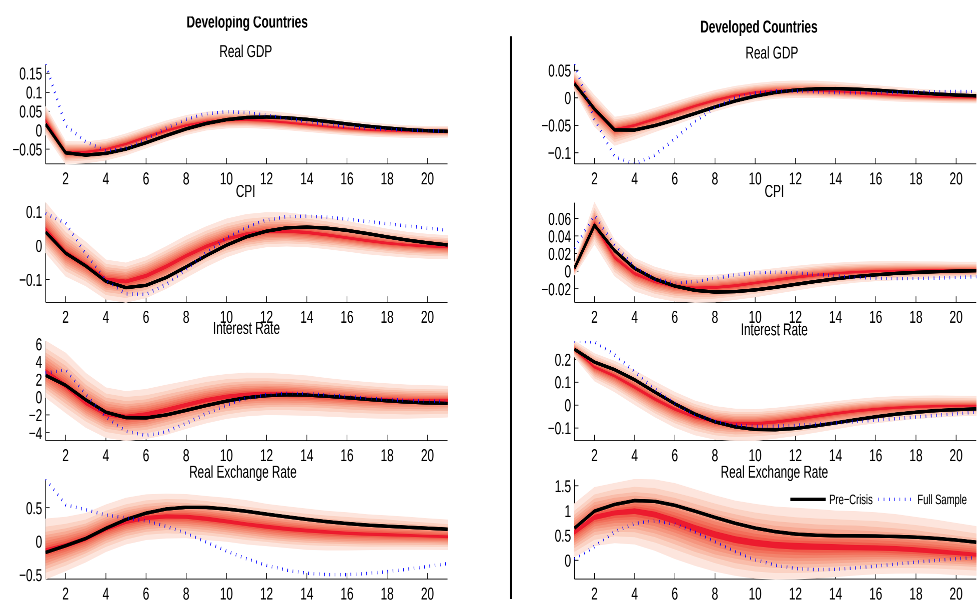

Figure 11: Impulse response functions to 50 basis points increase in U.S. federal funds rate for pre/after-crisis period

Figure 11 shows the impulse responses for the case of using shadow rate and samples covering the GFC period. Overall, the impulse responses are qualitatively similar, with two

[33]The impulse response function based on using the shadow rate instead of the federal funds rate in the pre-crisis period is quite similar to our baseline. They are available upon request. Shadow rate data is available on Jing Cynthia Wu's website or on Atlanta Fed's website.

exceptions. The first exception is related to the real exchange rate response in developing countries. In the whole sample, the real exchange rate appreciates immediately and starts to decrease, where in the pre-crisis sample it had as hump-shaped response. Second, in the whole sample spillovers of U.S. monetary policy to other countries, macro variables are larger in particular interest rates.

6 Conclusion

We use a structural dynamic factor model on large panel quarterly data over the period 1979-2015 to analyse the impact of U.S. monetary policy on the other countries. The data set incorporates data on the U.S. and other country-specific key macroeconomic variables, such as real GDP, CPI, short-term interest rate and real exchange rate. The estimated model suggests that monetary contraction in U.S. leads to a significant decrease in real GDP, with a typical inverted hump-shape for almost all countries. It reduces aggregate price levels, increases interest rates and leads to appreciation of the U.S. dollar against other currencies. The results of the estimated model are in line with the studies in the literature predicted by economic theory and tested in the empirical literature. However, the effect of U.S. monetary policy on the individual countries is heterogeneous. The responses of macroeconomic variables to the same U.S. monetary policy shock in developing countries is larger compared to developed countries. Moreover, we find that U.S. monetary policy during the global financial crisis has a somewhat stronger effect on interest rates, prices and real exchange rates in developing countries. We find that cross-country heterogeneity in responses is a consequence of difference in country specific characteristics, such as exchange, rate regimes, currency of price settings of firms, central bank independence and distance from the United States. For instance, adopting a flexible exchange rate regime with higher independence of the central bank weakens monetary spillovers from abroad.

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7 Appendix:

7.1 Selection criteria for number factors

Number of factors should be chosen to maximize the variance of observed data explained by the factors. The model with increasing the number of factors fits better but leads efficiency loss because of increasing estimated parameters. Bai and Ng (2002) (BN) suggest following criteria by modifying AIC and BIC with consideration of N, and T (cross-section dimension and time series dimension, respectively):

$$PC(r) = V(r) + rg(N,T) \tag{A.1}$$

where $V(r) = \frac{1}{NT}\sum_{i=1}^{N}\sum_{t=1}^{T}(X_{it} - \Lambda_i \hat{F}_t)$ is sum of squared residual from regression of observed data in r factors for all i and $g(N,T)$ is penalty function for overparameterization. r should minimize PC. BN proves that $g(N,T)$ should satisfies following conditions *i)* $g(N,T) \to 0$ and *ii)* $C_{N,T}$ $g(N,T) \to 0$ when $N,T \to \infty$ where $C_{N,T} = \min[\sqrt{N},]\sqrt{T}]$ to avoid under/over-estimation.

We assumed that factors are estimated by principal component method and $\hat{\sigma}^2$ is consistent estimate of $\frac{1}{NT}\sum_{i=1}^{N}\sum_{t=1}^{T}E(\varepsilon_{it})^2$.

$$PC_{p1}(r) = V(r) + r\hat{\sigma}^2(\frac{N+T}{NT})\ln(\frac{NT}{N+T}) \tag{A.2}$$

$$PC_{p2}(r) = V(r) + r\hat{\sigma}^2(\frac{N+T}{NT})\ln C_{N,T}^2 \tag{A.3}$$

$$PC_{p3}(r) = V(r) + r\hat{\sigma}^2(\frac{\ln C_{N,T}^2}{C_{N,T}^2}) \tag{A.4}$$

$$IC_{p1}(r) = \ln(V(r)) + r(\frac{N+T}{NT})\ln(\frac{NT}{N+T}) \tag{A.5}$$

$$IC_{p2}(r) = \ln(V(r)) + r(\frac{N+T}{NT})\ln C_{N,T}^2 \tag{A.6}$$

$$IC_{p3}(r) = \ln(V(r)) + r(\frac{\ln C_{N,T}^2}{C_{N,T}^2}) \tag{A.7}$$

where $V(r) = 1/N\sum_{i=1}^{N}\hat{\sigma}_i^2$ and $\hat{\sigma}_i^2 = \hat{\varepsilon}_i'\hat{\varepsilon}_i/T$.

Onatski (2010) develops a sequential procedure by applying the asymptotic distribution of the eigenvalues of the sample covariance matrix. The selection procedure is based on:

i) Compute eigenvalues $\lambda_1, ..., \lambda_n$ of the sample covariance matrix XX'/T and set $j = r_{\max}+1$;*ii) calculate* $\hat{\alpha}$, coefficient of OLS of eigenvalues $(\lambda_j, ..., \lambda_{j+4})$ on $(j-1)^{2/3}, ..., (j+3)^{2/3}$ and a constant, and set $\theta = 2\,|\hat{\alpha}|$; *iii)* compute $r(\theta) = max\,\{i \leq r_{\max} : \lambda_i - \lambda_{i+1} \geq \theta\}$ or if $\lambda_i - \lambda_{i+1} < \theta$ for all $i \leq r_{\max}$ and set $\hat{r}(\theta) = 0$*; iv) set* $j = \hat{r}(\theta) + 1$. Repeat steps 2 and 3 until convergence.

Amengual and Watson (2007) propose a two-step method by modifying BN to estimate number of dynamic factors under assumption of factors evolve as a VAR. Static factors are estimated from observed data by principal component method and the number of static factors is determined by applying BN method information criteria in the first step. In the second step, they apply BN information criteria to the sample covariance matrix of estimated residuals from regression of observed data on its lags of and factors to calculate the number of dynamic factors.

Bai and Ng (2007) develops an alternative criteria to estimate the number of dynamic factors. It is consist of following steps: *i)* Factors are obtained as defined above. The residuals, $\hat{\epsilon}_t$, are obtained from VAR in factors and $\hat{\Sigma}_\epsilon = 1/T \sum_{t=1} \hat{\epsilon}_t' \hat{\epsilon}_t$. *ii)* $\hat{D}_{a,k} = \left(\frac{\beta_{k+1}^2}{\sum_{j=1}^r \beta_j^2} \right)^{1/2}$ and $\hat{D}_{b,k} = \left(\frac{\sum_{j=k+1}^r \beta_j^2}{\sum_{j=1}^r \beta_j^2} \right)^{1/2}$ where $\beta_1 \geq \beta_2 \geq ... \geq \beta_r$ are eigenvalues of $\hat{\Sigma}_\epsilon$. *iii)* Lastly they apply following rules: $\kappa_a = \left\{ k : \hat{D}_{a,k} < g/\min\left[n^{1/2--\delta}, \right] T^{1/2-\delta} \right\}$ and $\kappa_b = \left\{ k : \hat{D}_{b,k} < g/\min\left[n^{1/2--\delta}, \right] T^{1/2-\delta} \right\}$ for $0 < g < \infty$ and $0 < \delta < 1/2$ and $\hat{q}_a = \min\{k \in \kappa_a\}$, $\hat{q}_b = \min\{k \in \kappa_b\}$.

The estimation results for the number of static and dynamic factors are summarized in Table 5.

Table 5: Number of Static and Dynamic Factors

	PC1	*PC2*	*PC3*	*IC1*	*IC2*	*IC3*	*Onatski*	*Average*
Static Factors	14	13	18	9	6	14	9	11.4
Number of Lags:								
BIC	1	1	5	1	1	1	1	1.5
Dynamic Factors:								
Bai-Ng1	6	5	7	4	3	4	3	4.5
Bai-Ng2	6	5	7	5	4	4	4	4.4
Bai-Ng3	8	8	11	5	4	5	4	5.5
Bai-Ng4	6	5	8	3	3	4	3	4.1
AW1	4	4	4	4	6	1	6	3.1
AW2	3	3	3	3	5	1	5	2.8

7.2 Evaluating latent factors

We construct statistics developed by Bai and Ng (2006) to compare observable economic variables with unobserved factors to assess how the observed variables are close (equal) to factors.

$G_{jt} = \gamma_j' F_t + \xi_{jt}$ where G_{jt} is vector of observed variable, F_t is vector latent factors estimated from full sample and $\hat{G}_{jt} = \hat{\gamma}_j' F_t$. The t-statistics defined as $\tau_t(j) = (\hat{G}_{jt} - G_{jt})/(var(\hat{G}_{jt}))^{1/2}$. Then $A(j)$ is the frequency that t-statistics exceeds the α percent critical value ϕ_α^τ in sample size of T. It is defined as following: $A(j) = 1/T \sum_{t=1}^{T} (|\tau_t(j)| > \phi_\alpha^\tau)$. $M(j)$ is statistics that examines how far is the estimated factors to observed factors. It is defined as $M(j) = \max_{1 \le t \le T} |\tau_t(j)|$.

The noise-to-signal ratio and R-square are structured as following respectively. $NS(j) = var(\hat{\xi}(j))/var(\hat{G}(j))$ and $R^2(j) = var(\hat{G}(j))/var(G(j))$. If $NS(j)$ is zero, it implies that estimated factor and observed variables are the same. Thus large values of $NS(j)$ suggest weaker relation between them. We also consider $R^2(j)$ to avoid definition of large and small $NS(j)$. Zero R^2 indicates that G_{jt} is irrelevant and unity indicates that it is an exact factor.

7.3 Exchange rate pass-through to import prices calculations:

Following Campa and Goldberg (2005) we calculate exchange rate pass-through into import prices using micro-foundations of pricing behaviour by exporters. In our specification a complete pass-through into import prices of goods represents pricing in the producer's currency and zero percent pass-through represents pricing in the local currency, when prices are rigid in the short-run.

By definition, the import prices for country i, $P_t^{m,i}$, expressed as follows:

$$P_t^{m,i} = P_t^{x,i} E_t^i \tag{A.8}$$

where E_t^i denotes exchange rate and $P_t^{x,i}$ denotes export prices of home country's trading partners. Export prices are sum of mark-up and exporter marginal cost and so equation (1) can be rewritten in logarithm as[34]

$$p_t^{m,i} = e_t^i + mkup_t^{x,i} + mc_t^{x,i} \tag{A.9}$$

We assume exporter marginal costs are growing with exporter market wages and importer demand

[34]Lowercase letters are used for logarithm.

$$mc_t^{x,i} = \lambda_1 y_t^{m,i} + \lambda_2 w_t^{x,i} \tag{A.10}$$

and mark-up is a function of industry specific fixed effect and macroeconomic conditions (for simplicity expressed in terms of only exchange rates):

$$mkup_t^{x,i} = \phi + \gamma e_t^i \tag{A.11}$$

Hence the importer prices can be written in general form plugging equation (3) and (4) into (2):

$$p_t^{m,i} = \phi + (1+\gamma)e_t^i + \lambda_1 y_t^{m,i} + \lambda_2 w_t^{x,i} \tag{A.12}$$

The exchange rate pass-through into import prices, $(1+\gamma)$ depends on mark-up sensitivity to market conditions. Producer's currency pricing takes place when $\gamma = 0$; local currency pricing takes place and exporters absorb variation in the exchange rate completely, when $\gamma = -1$.

We have used quarterly data on import price indices between 1979 and 2008 for thirty countries. The real GDP series are used as a proxy for of the importing countries demand conditions and unit of labour costs index is used as a proxy to represent exporter's cost. We estimate log-difference version of equation (5) applied ordinary least squares[35].

$$\Delta p_t^{m,i} = \alpha + \textstyle\sum_{j=0}^{4} \beta_j^i \Delta e_{t-j}^i + \Gamma_1^i \Delta y_t^{m,i} + \textstyle\sum_{j=0}^{4} \Gamma_{2,j}^i \Delta w_{t-j}^{x,i} + \varepsilon_t^i \tag{A.13}$$

The short-run exchange rate pass-through into import prices for country i is given by the estimated coefficient β_0^i . The long run elasticity is given by the sum of the coefficients on the contemporaneous exchange rate and four lags of exchange rate $\sum_{j=0}^{4} \beta_j^i$.

Estimates of exchange rate pass-through into import prices are presented in Table 6. Although the pass-through coefficients vary by country, we find that average unweighted pass-through into import prices is 0.40 in the short run and 0.46 in the long run. Developing countries have relatively high pass-through, 60% (64%) within one quarter (over one year) while developed countries have 24% (34%) within one quarter (over one year)[36]. We might infer from cross-country heterogeneity in ERPT into import prices that different currency choice occurs[37]. Hence ERPT elasticises can be used as a proxy for currency choice where

[35]We include up to four lags of exchange rates and exporter's production costs in the regression.

[36]The short-run exchange rate pass-through is negative for Singapore, but it is not significant.

[37]Since numerous papers in both micro and macro the literature find that there is a complete exchange rate pass-through into import prices of goods priced in the PCP strategy and zero percent ERPT for goods priced in LCP strategy when prices are rigid in the short-run. See Engel (2006), Gopinath et al. (2010), Goldberg and Verboven (2005) and among others.

high degree pass-through currency suggesting PCP and low degree pass-through suggesting LCP. Our empirical evidence of ERPT elasticity supports that LCP more likely appears in developed countries and PCP appears in developing and emerging countries which consistent with finding of Gopinath et al. (2010).

Table 6: EPRT into aggregate import prices

Countries	*Short-run*	*Conf. interval*	*Long run*
Argentina	1	[0.98 1.03]	1.01
Australia	0.51	[0.43 0.58]	0.51
Austria	0.06	[0.00 0.13]	0.18
Belgium	0.22	[0.12 0.32]	0.35
Brazil	1.03	[0.98 1.07]	0.99
Canada	0.47	[0.39 0.55]	0.2
Chile	0.94	[0.72 1.17]	0.72
China	0.95	[0.85 1.06]	0.99
Finland	0.14	[0.03 0.24]	0.23
France	0.16	[0.06 0.26]	0.35
Germany	0.12	[0.03 0.21]	0.31
India	0.04	[-0.32 0.40]	0.27
Indonesia	0.49	[0.37 0.61]	0.61
Italy	0.39	[0.24 0.54]	0.61
Japan	0.61	[0.45 0.77]	0.9
Korea	0.31	[0.17 0.46]	0.06
Malaysia	0.53	[0.39 0.67]	0.73
Netherlands	0.15	[0.05 0.24]	0.27
New Zealand	0.39	[0.28 0.50]	0.4
Norway	0.07	[-0.07 0.21]	0.16
Peru	0.04	[0.00 0.07]	0
Philippines	0.56	[0.31 0.81]	0.51
Singapore	-0.12	[-0.33 0.09]	0.12
South Africa	0.27	[0.18 0.37]	0.51
Spain	0.49	[0.31 0.66]	0.67
Sweden	0.14	[0.05 0.22]	0.2
Switzerland	0.04	[-0.02 0.10]	0.19
Thailand	0.61	[0.47 0.74]	0.49
Turkey	0.75	[0.61 0.90]	0.89
UK	0.22	[0.15 0.29]	0.42
Economic Level			
Developing Countries	0.60		0.64
Developed Countries	0.24		0.34

Note: Third coloumn is the 95 percent confidence interval for short-term exchange rate pass-through

7.4 An alternative identification method: Cholesky factorisation

In this subsection, we impose economically meaningful restrictions to identify structural shocks for the baseline model as in Forni et al. (2009).

If H is any orthogonal $q \times q$ matrix, then structural shocks in equation (4) can be written as $Ru_t = Sv_t$, where $S = RH'$, $v_t = Hu_t$. Hence, $\chi_t = c(L)v_t$, with $c(L) = b(L)H' = \Lambda\Phi(L)^{-1}S$. With no loss of generality, m variables of interest can be selected. Then for these selected variables $\chi_{mt} = C_m(L)v_t$, where $B_m(L) = C_m(L)H$ and $H'H = I_q$. Now, imposing some restrictions implied by economic theory is adequate to obtain the orthogonal matrix, H and, therefore, the impulse-response functions, $b(L)$.

We order variables in a standard VAR in a particular Wold causal chain to achieve exact identification. Identification proceeds using a Cholesky factorisation of the factor innovation variance matrix. Since the purpose of this study is to identify U.S. monetary policy shock, we select the following variables in order: U.S. real GDP, U.S. CPI, fed funds rates and real exchange rate (and other countries' short-term interest rates, if any). Monetary policy shocks do not affect economic activity and price level within the quarter, but affect financial variables like exchange rate and other countries' short-term interest rates.

We carry out the following estimation procedure, as in Forni et al. (2009):

1. The static factors F_t are estimated as the principal components of the stationary standardised X_t panel and so factor loadings (Λ) for given number of factors. The number of static factors can be estimated using the information criteria approach. Let X_t be the standardised data matrix and $\Sigma_x = X'X$ be the variance-covariance matrix of X_t. Then Λ can be estimated by using the normalisation $\Lambda'\Lambda/n = I_r$ as $\hat{\Lambda} = W\sqrt{n}$ is a matrix containing eigen vectors corresponding to the first r largest eigenvalue of Σ_x, and estimated static factors $\hat{F}_t = X_t\hat{\Lambda}/n$.

2. Given the estimates F_t , the VAR coefficients are estimated by first regressing F_t onto the desired number of lags (p) to obtain the estimator of $\Phi(L)$ and residuals ε_t. The number of dynamic factors is estimated using statistics proposed by Bai and Ng (2007).

3. Let $\Sigma_\varepsilon = E(\varepsilon_t'\varepsilon_t)$ be the variance-covariance matrix of residuals ε_t. Spectral decomposition of Σ_ε is used to estimate q dynamic factors. In particular, μ_ε^i where $i = 1...q$, is ith eigenvalue of Σ_ε, in decreasing order, M diagonal matrix with $\sqrt{\mu_\varepsilon^i}$ as (i,i) entry, K_i a unit-modulus column eigen vector corresponding to μ_ε^i, and $K = (K_1, K_2, ...Kq)$. Defining $\hat{S} = KM$, estimated impulse response function is $\hat{C}(L) = \hat{\Lambda}\hat{\Phi}(L)^{-1}\hat{S}$. Hence $\hat{H}$ and response functions $\hat{B}_m(L) = \hat{C}_m(L)\hat{H}$ can be obtained by imposing restriction on m selected variables.

7.5 Data description

This appendix describes the data, their sources and transformations. U.S. data set includes 106 individual monthly and 34 quarterly series from 1979Q1-2015Q2. The series were available monthly were converted to quarterly.

The data set for non-U.S. countries covers four main macroeconomics variables at quarterly frequency: real GDP, CPI, short term interest rate and real exchange rate. All U.S. time series are directly taken from Stock and Watson, and data for non-U.S. countries is taken from Global VAR database.

Real exchange rate: It was computed using the formula $Qt = S_t^*(P_t^*/Pt)$, where the nominal exchange rate is S_t (price of US currency in terms of domestic currency, US CPI is P_t^* and domestic CPI is P_t.

Transformation: The series were converted using transformation codes are listed in Table 7 Transformation codes are: 1 - no transformation; 2- first difference; 3- second difference; 4 - logarithm; 5 - first difference of logarithm.

Outliers: Outliers were detected as values differing from the sample median more than 4.5 times the interquartile difference and replaced with the median of the five previous observations.

Seasonal Adjustment: Majority of series were seasonally adjusted by the source. We applied X-12-ARIMA seasonal adjustment technique to adjust the series are not seasonally adjusted.

Table 7: Data Series

	Description	Transformation
U.S. related variables (140)		
1	Real Gross Domestic Product 3 Decimal	5
2	Real Personal Consumption Expenditures	5
3	Real Gross Private Domestic Investment 3 Decimal	5
4	Real Nonresidential Investment: Equipment Quantity Idenx	5
5	Real Government Consumption Expenditures and Gross Investment 3 Decimal	5
6	Real Federal Consumption Expenditures Quantity Index	5
7	Real Exports Of Goods and Services Quantity Index	5
8	Real Imports Of Goods And Services Quantity Index	5
9	Nonfarm Business Sector: Output	5
10	Business Sector: Output	5
11	Nominal Disp. Personal Income. (Used To Construct Liability Ratios)	1
12	Ip: Total Index	5
13	Industrial Production: Final Products (Market Group)	5
14	Ip: Consumer Goods	5
15	Industrial Production: Materials	5
16	Industrial Production: Durable Materials	5
17	Industrial Production: Nondurable Materials	5
18	Industrial Production: Durable Consumer Goods	5
19	Ip: Automotive Products	5
20	Industrial Production: Nondurable Consumer Goods	5
21	Industrial Production: Business Equipment	5
22	Capacity Utilization In Manufacturing	1
23	All Employees: Total Private Industries	5
24	All Employees: Manufacturing	5
25	All Employees: Service-Providing Industries	5
26	All Employees: Goods-Producing Industries	5
27	All Employees: Durable Goods Manufacturing	5
28	All Employees: Nondurable Goods Manufacturing	5
29	All Employees: Construction	5
30	All Employees: Education and Health Services	5
31	All Employees: Financial Activities	5
32	All Employees: Information Services	5
33	All Employees: Professional and Business Services	5
34	All Employees: Leisure and Hospitality	5
35	All Employees: Other Services	5
36	All Employees: Natural Resources and Mining	5
37	All Employees: Trade Transportation and Utilities	5
38	All Employees: Government	5
39	All Employees: Retail Trade	5
40	All Employees: Wholesale Trade	5
41	Employment Federal Government	5
42	Employment State Government	5
43	Employment Local Government	5
44	Emp Total (Household Survey)	5
45	Laborforce Participation Rate (16 Over) Sa	2
46	Unemployment Rate	1

47	Urate Short Term (¡ 27 Weeks)	1
48	Urate Long Term (¿= 27 Weeks)	1
49	Unemployment Rate - 16-19 Yrs	1
50	Unemployment Rate - 20 Yrs. and Over Men	1
51	Unemployment Rate - 20 Yrs. and Over Women	1
52	Number Unemployed For Less Than 5 Weeks	5
53	Number Unemployed For 5-14 Weeks	5
54	Civilians Unemployed For 15-26 Weeks	5
55	Number Unemployed For 27 Weeks and Over	5
56	Business Sector: Hours Of All Persons	5
57	Nonfarm Business Sector: Hours Of All Persons	5
58	Average Weekly Hours: Manufacturing	1
59	Average Weekly Hours: Total Private Industrie	1
60	Average Weekly Hours: Overtime: Manufacturing	1
61	Housing Starts: Total: New Privately Owned Housing Units Started	4
62	Housing Starts In Midwest Census Region	4
63	Housing Starts In Northeast Census Region	4
64	Housing Starts In South Census Region	4
65	Housing Starts In West Census Region	4
66	Mfrs New Orders Consumer Goods And Materials (Mil. 1982 Dollar)	5
67	Mfrs Unfilled Orders Durable Goods Indus. (Bil. Chain 2000 Dollar)	5
68	Mfrs New Orders Nondefense Capital Goods (Mil. 1982 Dollar)	5
69	Ism Manufacturing: Supplier Deliveries Index	1
70	Ism Manufacturing: Inventories Index	1
71	Ism Manufacturing: New Orders Index	1
72	Manufacturing And Trade Inventories (Bil. Chain 2005 Dollar)	5
73	Personal Consumption Expenditures: Chain-Type Price Index	5
74	Personal Consumption Expenditures: Chain-Type Price Index Less Food And Energy	5
75	Personal Consumption Expenditures: Chain-Type Price Index	5
76	Personal Consumption Expenditures: Chain-Type Price Index Less Food And Energy	5
77	Gross Domestic Product: Chain-Type Price Index	5
78	Gross Private Domestic Investment: Chain-Type Price Index	5
79	Business Sector: Implicit Price Deflator	5
80	Consumer Price Index For All Urban Consumers: All Items	5
81	Consumer Price Index For All Urban Consumers: All Items Less Food and Energy	5
82	Producer Price Index: Finished Goods	5
83	Producer Price Index: Finished Consumer Goods	5
84	Producer Price Index: Finished Consumer Foods	5
85	Producer Price Index: Industrial Commodities	5
86	Producer Price Index: Intermediate Materials: Supplies and Components	5
87	Average Hourly Earnings: Total Private Industries	5
88	Average Hourly Earnings: Construction	5
89	Average Hourly Earnings: Manufacturing	5
90	Nonfarm Business Sector: Real Compensation Per Hour	5
91	Business Sector: Real Compensation Per Hour	5
92	Nonfarm Business Sector: Output Per Hour Of All Persons	5
93	Business Sector: Output Per Hour Of All Persons	5
94	Business Sector: Unit Labor Cost	5
95	Nonfarm Business Sector: Unit Labor Cost	5
96	Nonfarm Business Sector: Unit Nonlabor Payments	5

97	Effective Federal Funds Rate	1
98	Wu-Xia Shadow Federal Funds Rate (Last Business Day Of Month)	1
99	3-Month Treasury Bill: Secondary Market Rate	1
100	6-Month Treasury Bill: Secondary Market Rate	1
101	1-Year Treasury Constant Maturity Rate	1
102	10-Year Treasury Constant Maturity Rate	1
103	Moodys Seasoned Aaa Corporate Bond Yield	1
104	Moodys Seasoned Baa Corporate Bond Yield	1
105	Baa-Gs10 Spread	1
106	Tb6m-Tb3m	1
107	Gs1-Tb3m	1
108	Gs10-Tb3m	1
109	Cp3fm-Tb3ms	1
110	St. Louis Adjusted Monetary Base; Bil. Of Dollar; M; Sa;	5
111	M1 Money Stock	5
112	M2sl	5
113	Mzm Money Stock	5
114	Commercial And Industrial Loans At All Commercial Banks	5
115	Consumer (Individual) Loans At All Commercial Banks	5
116	Total Nonrevolving Credit Outstanding	5
117	Real Estate Loans At All Commercial Banks	5
118	Total Revolving Credit Outstanding	5
119	SandPs Common Stock Price Index: Composite (1941-43=10)	5
120	Households And Nonprofit Organizations; Total Assets	5
121	Households And Nonprofit Organizations; Total Assets	5
122	Liabilities Relative To Person Disp Income	5
123	Networth Relative To Personal Disp Income	1
124	Households And Nonprofit Organizations; Total Nonfinancial Assets	5
125	Common Stock Prices: Dow Jones Industrial Average	5
126	House Price Index For The United States	5
127	Frb Nominal Major Currencies Dollar Index (Linked To Exrus In 1973:1)	5
128	Foreign Exchange Rate: Switzerland (Swiss Franc Per U.S. Dollar)	5
129	Foreign Exchange Rate: Japan (Yen Per U.S.Dollar)	5
130	Foreign Exchange Rate: United Kingdom (Cents Per Pound)	5
131	Foreign Exchange Rate: Canada (Canadian Dollar Per U.S.Dollar)	5
132	OECD: GDP By Expenditure In Constant Prices: Total Gross; Growth Rate (Quartely)	1
133	OECD: Total Ind. Prod (Excl Construction) Europe Growth Rate (Quarterly)	1
134	Consumer Expectations Nsa (Copyright University Of Michigan)	1
135	World Oil Production.1994:Q1 On From Eia (Crude Oil Including Lease Condensate)	5
136	IP: Consumer Energy Products	5
137	US Ending Stocks Excluding Spr Of Crude Oil and Petroleum Products (Thousand Barrels)	5
138	PPI: Crude Petroleum	5
139	U.S. Crude Oil Imported Acquisition Cost By Refiners (Dollars Per Barrel)	5
140	CPI Gasoline	5
	non U.S. related variables (120)	
141	Real Gross Domestic Product	5
142	Consumer Price Index	5
143	Short Term Interest Rate	1
144	Real Exchange Rate	4

Country-specific characteristic data: *Exchange rate regime classification:* We use updated version of Reinhart-Rogoff exchange rate regime classification. The data is available in Carmen Reinhart's website. They use market data and assess the conditional probability an exchange rate will move outside a certain range over a five year window. See Reinhart and Rogoff for more detail of classification. Alternatively, classification of IMF, Levy-Yeyati and Sturzenegger (2005) can be used.

The degree of exchange rate pass-through: This data created by author by calculating exchange rate pass-through on import prices using micro-foundations of pricing behavior by exporters.

Central bank independence: This measure constructed by Crowe and Meade (2007) using 2003 IMF's central bank laws data.

Distance: Distance to USA is calculated latitudes and longitudes of the capital cities from Mayer and Zignago (2006).

Tariffs: These estimates are calculated as simple mean applied tariff for all traded goods by World Bank.

Table 8: Categorize countries

Groups According to Economic Levels:				
Developed Economies (19):				
Australia	Finland	Japan	New Zealand	Switzerland
Austria	France	Korea	Singapore	UK
Belgium	Germany	Netherlands	Spain	US
Canada	Italy	Norway	Sweden	
Developing Economies (12):				
Argentina	Chile	Malaysia	South Africa	
Brazil	India	Peru	Thailand	
China	Indonesia	Philippines	Turkey	
Groups According to Geography:				
North America (2):				
Canada	US			
Latin America (4):				
Argentina	Brazil	Chile	Peru	
Europe(12):				
Austria	France	Netherlands	Sweden	
Belgium	Germany	Norway	Switzerland	
Finland	Italy	Spain	UK	
Asia (9):				
China	Indonesia	Korea	Philippines	Thailand
India	Japan	Malaysia	Singapore	
Australasia (2):				
Australia	New Zealand			
Others (2):				
South Africa	Turkey			