If the Fed sneezes, who catches a cold?

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Indroduction

outline

- the international **repercussions of U.S. monetary policy shocks.**
  - Motivation; Contribution; Contribution
- Brief introduction to BVAR
  - Why use it? shinkage prior and precise.
  - Do not discuss MCMC specific algorithms (MH and Gibbs)
  - BEAR(5.0)
  - There is a lot of content. By sharing, I hope everyone can use BVAR.
- Detailed interpretation of the impact of the Fed's monetary policy on itself and the world economy

Indroduction

Motivation

- This paper offers a re-examination of the international **repercussions of U.S. monetary policy shocks.**
  - Does a monetary contraction in the U.S. lead to recessions or expansions in other countries?
  - Does a monetary contraction improve or worsen financial conditions abroad?
  - Does it lead to capital inflows or outflows?
  - Are spillovers different across advanced and emerging economies, or across countries pegging their exchange rate to the dollar and those retaining monetary autonomy?

Empirical answers remain controversia (Bernanke, 2015)

- on **a limited set of countries** (e.g., G7 countries, as in Kim, 2001)
- on **a limited set of variables** (mainly output, inflation, short-term rates and bilateral dollar exchange rates as in e.g., Miniane and Rogers, 2007).

Indroduction

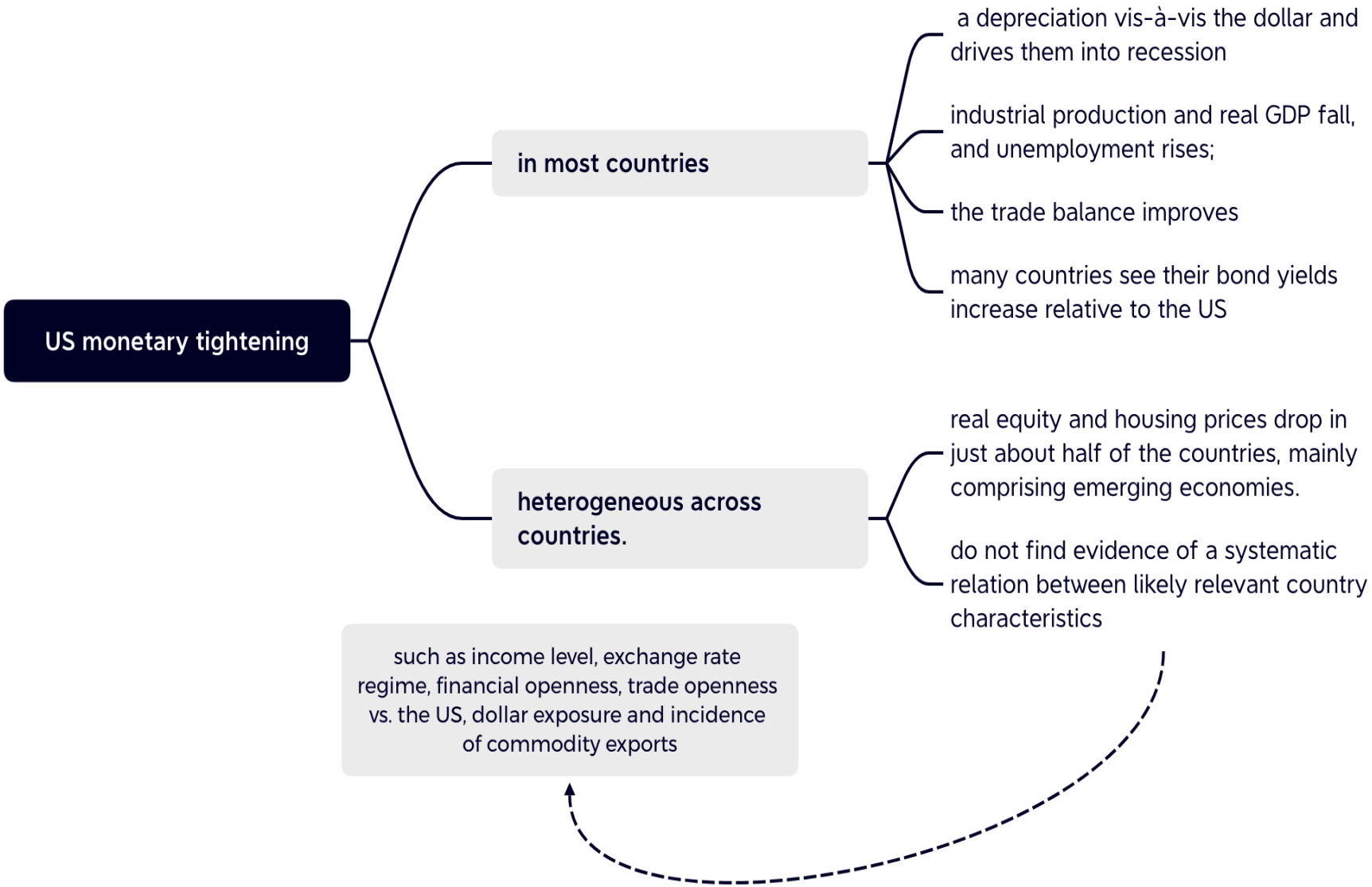
Contribution

- documenting the effects of US monetary policy shocks on **a broad set of macroeconomic and financial variables** in **18 advanced and 18 emerging economies.**
  a. **identify** US monetary policy shocks
  b. most importantly, in order to better understand **the international transmission of monetary policy**
     - ⋆ **variables** such as equity and housing prices, credit, and bank and portfolio flows.

Empirical approach

- First, we **estimate** US monetary policy shocks in a **structural VAR** identified with **sign restrictions.**
- We then regress third country variables on estimated shocks.

Main findings



(Recall OLS)
Estimation of the regression parameters
Starting from the concise matrix notation:

$$Y = BZ + U$$

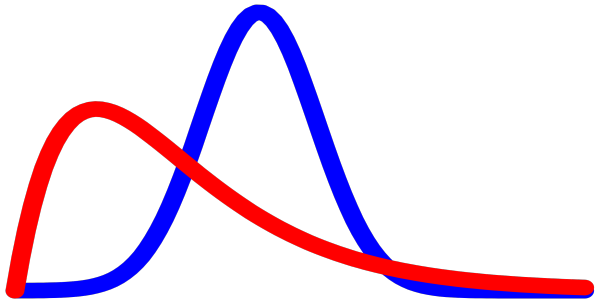
- The multivariate least squares (MLS) approach for estimating B yields:

$$\hat{B} = YZ' \left(ZZ'\right)^{-1}$$

As the explanatory variables are the same in each equation, the multivariate least squares estimator is equivalent to the ordinary least squares estimator applied to each equation separately.

OLS—>BVAR

- 为什么要用 BVAR?
  - 在小样本和 VAR 模型参数过多时，凸显优势 (shrinkage prior)。
  - BVAR 来源于经验或历史资料的先验信息来增加估计和预测的准确性。



Reference:

- Koop, G.; Korobilis, D. (2010). "Bayesian multivariate time series methods for empirical macroeconomics" (PDF). Foundations and Trends in Econometrics. 3 (4): 267–358.
- Giannone, D., Lenza, M., Primiceri, G., 2015. Prior selection for vector autoregressions. Rev. Econ. Stat. 97 (2), 436–451.
- 《向量自回归模型及其应用》叶阿忠等，2017 年 9 月。

2. Empirical approach

贝叶斯估计 (Bayesian Estimation) 的基本原理，直观地说非常简单，就是在参数先验分布 (Prior) 的基础上，结合数据的信息 (Y^{data})，找到参数的后验分布 (Posterior)。也就是说，贝叶斯估计的实质就是一个简单的映射，依据数据信息，将先验分布映射成后验分布。由于先验分布是依据经验而假设的分布，可能存在“偏误”，而数据的作用其实是“纠偏”，将其中有用的信息融入，以“纠正偏误”，从而形成后验分布，如图 3.10 所示。

图 3.10　贝叶斯估计的基本原理

从逻辑推导上说，贝叶斯估计背后就是概率论中著名的贝叶斯法则 (Bayes' Rule)，即参数的后验分布由条件概率公式：

$$p\left(Y^{\text{data}}|\theta\right)\times p(\theta)=p\left(Y^{\text{data}},\theta\right)=p\left(\theta|Y^{\text{data}}\right)\times p\left(Y^{\text{data}}\right) \tag{3.10.1}$$

推导出来：

$$p\left(\theta|Y^{\text{data}}\right)=\frac{p\left(Y^{\text{data}}|\theta\right)\times p(\theta)}{p\left(Y^{\text{data}}\right)} \tag{3.10.2}$$

BVAR 先验分布

- 无信息先验分布（Noninformative）
  - 对 θ 的任何取值都同等无知，不知道哪一部分的值更容易出现。
- 共轭先验（Natural Conjugate）
  - 有一定理论基础
  - 先验分布和后验分布数以同一类族
  - 超参数很多
  - **Minnesota 分布；**Natural Conjugate；**Normal Wishart；**（与贝叶斯常见先验分布有点区别）

THE BAYESIAN ESTIMATION, ANALYSIS AND REGRESSION (BEAR) TOOLBOX

TECHNICAL GUIDE

Version 4.2 preliminary

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20 June 2018

BVAR–Minnesota prior— shrinkage prior

A typical example is the **shrinkage** prior, proposed by Robert Litterman (1979) and subsequently developed by other researchers at University of Minnesota(i.e. Sims C, 1989), which is known in the BVAR literature as the **"Minnesota prior".**

VAR(P)：

$$\mathrm{y_{it}} = \sum_{\mathrm{j}=1}^{\mathrm{k}} \sum_{\tau=1}^{\mathrm{p}} \alpha_{\mathrm{ij}\tau} \mathrm{y_{jt-}}_{\tau} + \mu_{\mathrm{it}}, \mathrm{i} = 1, 2, \cdots, \mathrm{k}; \mathrm{t} = 1, 2, \cdots, \mathrm{n}$$

- $\alpha_{\mathrm{ij}\tau}$ 相互独立，且 $\alpha_{\mathrm{ij}\tau} \sim \mathrm{N}\left(\delta_{\mathrm{ij}\tau}, \mathrm{S}_{\mathrm{ij}\tau}^2\right)$，$\delta_{\mathrm{ij}\tau}$ 表示参数 $\alpha_{\mathrm{ij}\tau}$ 的最佳猜测值，而先验方差 $\mathrm{S}_{\mathrm{ijz}}^2$ 反映了对这个猜测的信心，其取值大小与信心成反比；**需要确定 $2k^2p$ 个超参数**
- 均值 $\delta_{\mathrm{ij}\tau}$ 取值满足如下式子:

$$\delta_{\mathrm{ij}\tau} = \begin{cases} 1, & \mathrm{i} = \mathrm{j}, \\ 0, & \text{else} \end{cases}$$

- 除了方程左边变量自身的一阶滞后变量的系数的先验期望为 1 外，方程中的其他变量的先验期望均为 0；

- 标准差 $\mathrm{S_{ijT}}$ 可分解为如下 4 个因子的乘积:

$$\mathrm{S_{ij\tau}} = \gamma \cdot \mathrm{g}(\tau) \cdot \mathrm{f(i,j)} \cdot \frac{\mathrm{s_i}}{\mathrm{s_j}}$$

- 其中, γ 为总体紧度 (overall tightness)，它的大小反映了分析人员对先验信息的信心大小的程度, 其取值大小与对先验信息的把握大小成反比;
- $g(\tau)$ 表示 τ 阶滞后变量对一阶变量的相对紧度, 表示过去信息比当前信息有用程度的减少。
  - 一般采用调和滞后延迟函数: $g(\tau) = \tau^{-d}, d > 0$; 随着滞后长度的增加, 滞后变量的系数趋向于零。
  - d 值越大，紧度 $\mathrm{g}(\tau)$ 越小, 进而 $\mathrm{S_{ij\tau}}$ 下降;
- 函数 $\mathrm{f(i,j)}$ 是第 i 个方程中第 j 个变量相对于第 i 个变量的紧度。
- 确定了 $\mathrm{g}(\tau)$ 与 γ 后, 先验分布中超参数数量从 $\mathrm{k^2p}$ 个减少为 $\mathrm{k^2} + 2$ $\left[\mathrm{k^2}\right.$ 个紧度函数 $\mathrm{f(i,j)}$, 再加上 $\mathrm{g}(\tau)$ 与 $\left.\gamma\right]$ 个。
- 确定合适的 $f(i,j)$ 以进一步减少先验分布中的参数个数。$f(i,j)$ 可以看作 $k \times k$ 矩阵 $FA(f(i,j))_{k\times k}$ 的 (i,j) 处的元素，一般 $f(i,j)$ 可以设为如下作 $\mathrm{k \times k}$ 形式:

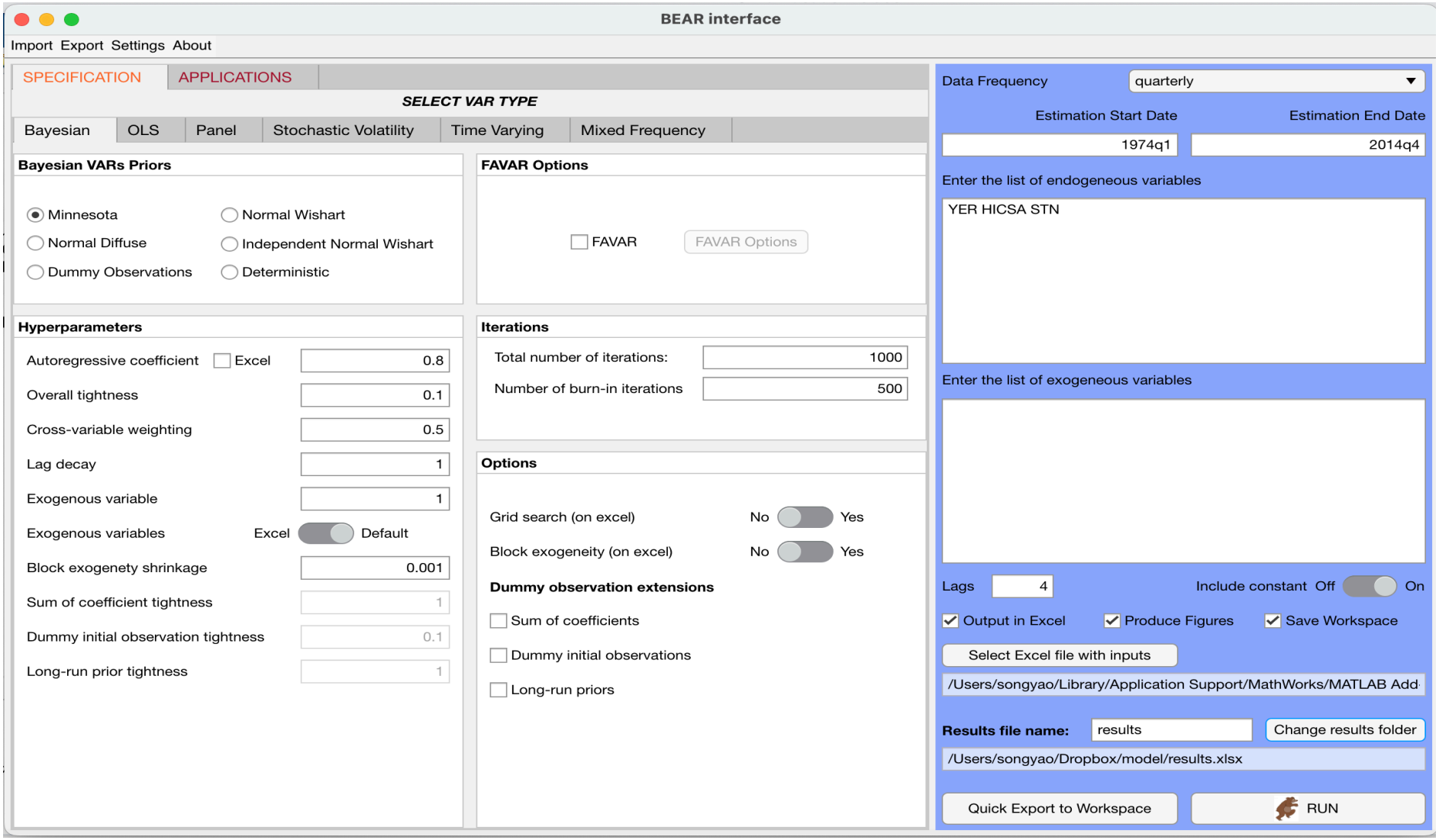
$$f(i,j) = \begin{cases} 1, i = j, \\ w_{ij}, \quad i \neq j, \end{cases}$$

- 其中，w_{ij} 是介于 0 与 1 之间的一个常数，它的取值反映了第 i 个方程后其他变量的相对紧度。如果 $\mathrm{i} \neq \mathrm{j}$ 情况下，$\mathrm{w_{ij}}$ 为一个不变常数，则 k^2 个参数 $\mathrm{f(i,j)}$ 的选取问题转化为确定一个超参数 w 的大小。
- $\mathrm{s_i}/\mathrm{s_j}$ 是第 i 个序列 $\{\mathrm{y_{it}}\}$ 的自回归残差标准差与第 j 个序列 $\{\mathrm{y_{jt}}\}$ 自回归残差标准差之比。
- $\mathrm{s_i}/\mathrm{s_j}$ ： **先验分布的设定必须考虑实际的样本数据信息。**
- 比如：滞后长度为 2 阶的双变量 VAR(2) 模型，该模型系数的 Minnesota 先验分布为:

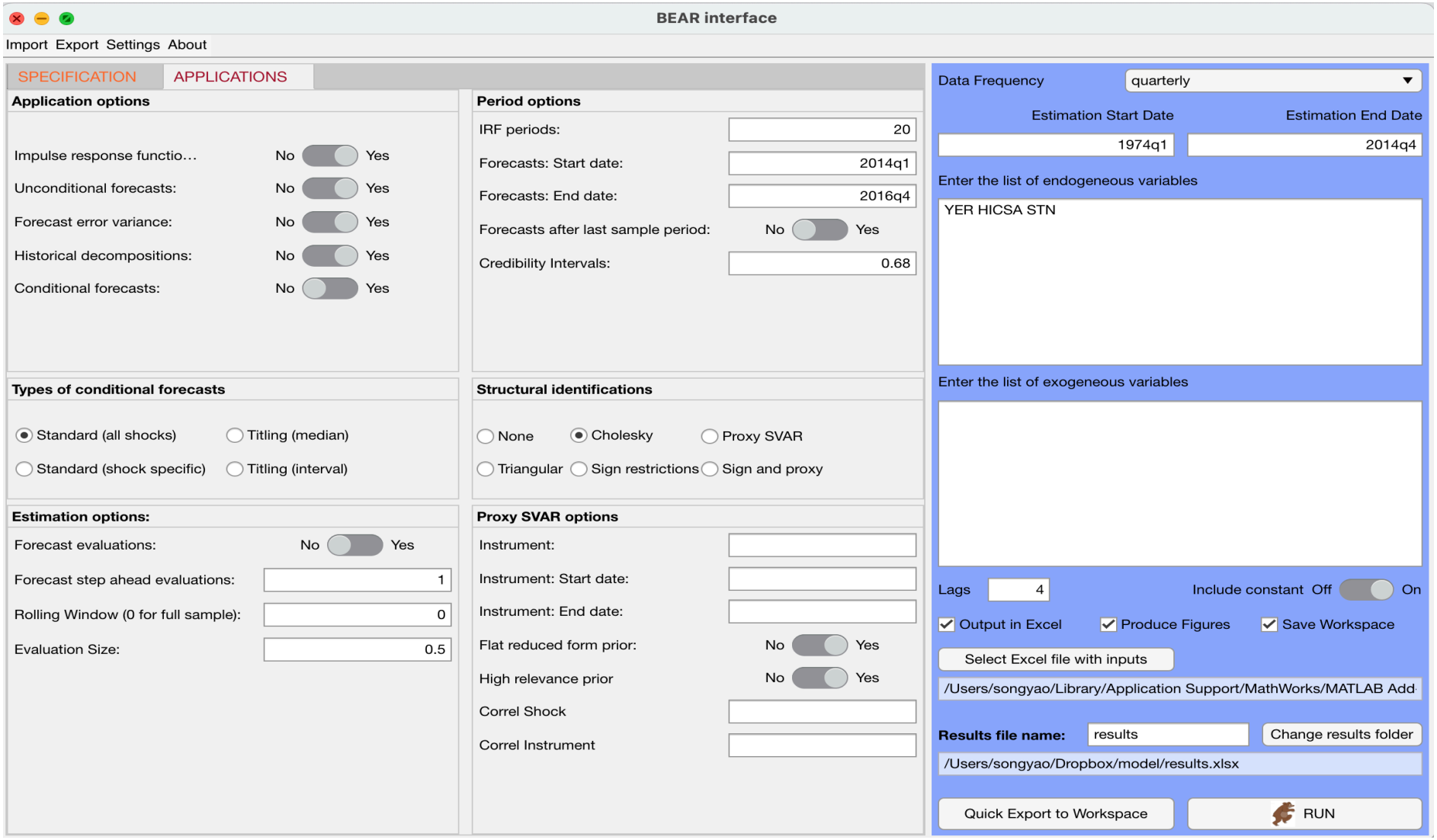
$$
\begin{cases}
\mathrm{y_{1t}} = \alpha_{111}\mathrm{y_{1t-1}} + \alpha_{112}\mathrm{y_{1t-2}} + \alpha_{121}\mathrm{y_{2t-1}} + \alpha_{122}\mathrm{y_{2t-2}} + \mu_{1t} \\
\qquad (1,\gamma)\ \left(0, \frac{\gamma}{2^{\mathrm{d}}}\right)\ \left(0, \frac{\gamma \mathrm{w_{12}}\ \mathrm{s_1}}{\mathrm{s_2}}\right)\ \left(0, \frac{\gamma \mathrm{w_{12}}\ \mathrm{s_1}}{2^{\mathrm{d}}\mathrm{s_2}}\right) \\
\mathrm{y_{2t}} = \alpha_{211}\mathrm{y_{1t-1}} + \alpha_{212}\mathrm{y_{1t-2}} + \alpha_{221}\mathrm{y_{2t-1}} + \alpha_{222}\mathrm{y_{2t-2}} + \mu_{2t} \\
\left(0, \frac{\gamma \mathrm{w_{21}}\ \mathrm{s_2}}{\mathrm{s_1}}\right)\ \left(0, \frac{\gamma \mathrm{w_{21}}\ \mathrm{s_2}}{2^{\mathrm{d}}\mathrm{s_1}}\right)\ (1,\gamma)\ \left(0, \frac{\gamma}{2^{\mathrm{d}}}\right)
\end{cases}
$$

括号内的第一项为该系数先验分布的均值，第二项为该系数先验分布的方差。

The Bayesian Estimation, Analysis and Regression toolbox **BEAR**) is a comprehensive (Bayesian Panel) VAR toolbox for forecasting and policy analysis.



2. BEAR


BEAR interface
Import Export Settings About
SPECIFICATION
APPLICATIONS
Application options
Impulse response functio… No Yes
Unconditional forecasts: No Yes
Forecast error variance: No Yes
Historical decompositions: No Yes
Conditional forecasts: No Yes
Period options
IRF periods: 20
Forecasts: Start date: 2014q1
Forecasts: End date: 2016q4
Forecasts after last sample period: No Yes
Credibility Intervals: 0.68
Types of conditional forecasts
Standard (all shocks) Titling (median)
Standard (shock specific) Titling (interval)
Structural identifications
None Cholesky Proxy SVAR
Triangular Sign restrictions Sign and proxy
Estimation options:
Forecast evaluations: No Yes
Forecast step ahead evaluations: 1
Rolling Window (0 for full sample): 0
Evaluation Size: 0.5
Proxy SVAR options
Instrument:
Instrument: Start date:
Instrument: End date:
Flat reduced form prior: No Yes
High relevance prior No Yes
Correl Shock
Correl Instrument
Data Frequency quarterly
Estimation Start Date 1974q1
Estimation End Date 2014q4
Enter the list of endogeneous variables
YER HICSA STN
Enter the list of exogeneous variables
Lags 4
Include constant Off On
Output in Excel
Produce Figures
Save Workspace
Select Excel file with inputs
/Users/songyao/Library/Application Support/MathWorks/MATLAB Add
Results file name: results
Change results folder
/Users/songyao/Dropbox/model/results.xlsx
Quick Export to Workspace
RUN

2.1. The BVAR model

Specifically, the reduced form VAR model for n variables,

$$Y_t = BY_{t-1} + \varepsilon_t, \quad \varepsilon_t \sim N(0, \Sigma)$$

As regards priors, **a Normal —Inverse-Wishart distribution** is used for the coefficients and the variance—covariance matrix, namely

$$\Sigma \sim \mathrm{IW}\left(\psi I_n; n+2\right)$$
$$\mathrm{vec}(B) \mid \Sigma \sim N(b, \Sigma \otimes \Omega)$$

- where $b(\gamma)$ and $\Omega(\gamma)$ are functions of a small vector of hyperparameters γ.
- The scale parameter ψ is also a hyper-parameter, which follows a diffuse prior, $\psi \sim IG\left(0.02^2, 0.02^2\right)$.
- Bayesian shrinkage is achieved through the combination of Minnesota
- an MCMC algorithm is used for inference, based on a Metropolis step to draw the vector of hyper-parameters and on a standard Gibbs sampler to draw the model's parameters conditional on the former.

Wishart distribution(From Wikipedia, the free encyclopedia)
Suppose G is a $p \times n$ matrix, each column of which is independently drawn from a p-variate normal distribution with zero mean:

$$G_i = \left(g_i^1, \ldots, g_i^p\right)^T \sim N_p(0, V).$$

Then the Wishart distribution is the probability distribution of the $p \times p$ random matrix $S = GG^T = \sum_{i=1}^{n} G_i G_i^T$ known as the scatter matrix. One indicates that S has that probability distribution by writing

$$S \sim W_p(V, n).$$

The positive integer n is the number of degrees of freedom. Sometimes this is written $W(V, p, n)$. For $n \geq p$ the matrix S is invertible with probability 1 if V is invertible. If $p = V = 1$ then this distribution is a chi-squared distribution with n degrees of freedom.
Distribution of the inverse of a Wishart-distributed matrix
If $\mathbf{X} \sim \mathcal{W}(\mathbf{\Sigma}, \nu)$ and $\mathbf{\Sigma}$ is of size $p \times p$, then $\mathbf{A} = \mathbf{X}^{-1}$ has an inverse Wishart distribution $\mathbf{A} \sim \mathcal{W}^{-1}\left(\mathbf{\Sigma}^{-1}, \nu\right)$.

2.2. Identification

it convenient to impose priors to identify US monetary policy shocks through **sign restrictions** on the impulse response functions

$$
\begin{aligned}
&FFR > 0 \quad \text{for} \quad t = 1, \ldots, 6 \\
&IP_{US} < 0 \quad \text{for} \quad t = 2, \ldots, 6 \\
&CPI_{US} \leq 0 \quad \text{for} \quad t = 4 \\
&1Y - GBY_{US} > 0 \quad \text{for} \quad t = 1, \ldots, 4 \\
&MS_{US} > 0 \quad \text{for} \quad t = 2 \\
&CPS_{US} > 0 \quad \text{for} \quad t = 1, 2, 3 \\
&SP_{US} < 0 \quad \text{for} \quad t = 1 \\
&NEER_{US} > 0 \quad \text{for} \quad t = 1 \\
&DiffIR < 0 \quad \text{for} \quad t = 1
\end{aligned}
$$

- Here FFR is the Fed Funds rate, IP_{US} is the US industrial production, CPI_{US} is the US consumer price index, $1Y - GBY_{US}$ are 1-year government bond yields, MS_{US} is the mortgage spread, CPS_{US} is the commercial paper spread, SP_{US} is the $S\&P500$ index, $NEER_{US}$ is the nominal effective exchange rate, and $DiffIR$ is the difference between the G7 interest rate and the US short-term rate.

proposed in Uhlig (2005), Recall that any candidate contemporaneous response to the vector of structural shocks can be calculated as

$$H = PQ$$

where P is the Choleski factor of the variance matrix of the reduced form innovations, $\Sigma = PP'$, and Q an orthogonal matrix obtained from the following decomposition

$$X = QR$$

where X is the realization of a matrix of independent $N(0, 1)$. These Q s are then used to compute candidate monetary shocks from the associated reduced form residuals; namely we have that

$$\varepsilon_{US,t}^{MP} = (PQ)^{-1}\varepsilon_t = (PQ)^{-1}(Y_t - BY_{t-1})$$

2.3. Estimation of the impact on countries other than the US

$$y_{it} = \alpha_{i,j} + \phi_i(L)y_{i,t-1} + \beta_i(L)\varepsilon_{US,t}^{MP} + \varepsilon_{it} \tag{1}$$

3. Data description

Our sample consist of 36 countries, namely: Australia, Austria, Belgium, Brazil, Canada, Chile, China, Colombia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, India, Italy, Japan, Korea, Latvia, Lithuania, Malaysia, Mexico, Netherlands, Norway, Philippines, Poland, Portugal, Russia, South Africa, Spain, Sweden, Thailand, Turkey and UK.
For each country we consider both monthly and quarterly variables. (1980-2013)

- Monthly variables include the following:
  - (i) the bilateral dollar exchange rate;
  - (ii) the real effective exchange rate;
  - (iii) the short-term interest rate differential with the US;
  - (iv) CPI;
  - (v) industrial production;
  - (vi) real stock prices (deflated with the CPI); the nominal trade balance (scaled by the average of the sum of import and export over the whole sample);
  - (vii)the differential of long-term government bond yields vis-á-vis the US.

3. Data description

- Quarterly variables include the following:
  - (i) real GDP;
  - (ii) the GDP deflator;
  - (iii) the unemployment rate;
  - (iv) real housing prices (deflated by CPI);
  - (v) real domestic credit (deflated by CPI);
  - (vi)—(vii) total portfolio inflows and outflows
  - (viii) total bank inflows, all scaled by GDP.
  - as a gauge of **macroeconomic volatility** we also report results for the sum of the absolute changes in unemployment and inflation (as measured by the GDP deflator), the so-called **"misery index"**

3.1. Country characteristics

We group countries on the basis of the following characteristics:

- Advanced vs. emerging economy
  - IMF World Economic Outlook
- Exchange rate regime
  - We mainly draw from **Klein and Shambaugh (2010)**, who also have some information on the base country.
- Financial openness
  - We measure financial openness with the **Chinn–Ito(2006)** index
- US trade exposure
  - We consider countries'trade linkages with the United States (exports to and imports from the US as a share of domestic GDP).
- Dollar exposure
  - This is computed on the basis of data in Benetrix et al. (2015) on the currency composition of gross foreign assets and liabilities.
- Commodity exporters
  - We define commodity exporters based on the incidence of net exports of primary goods over total exports plus imports. Primary goods include fuels (oil, gas, coal), metals, food and other raw materials.

4. The domestic effects of US monetary policy shocks

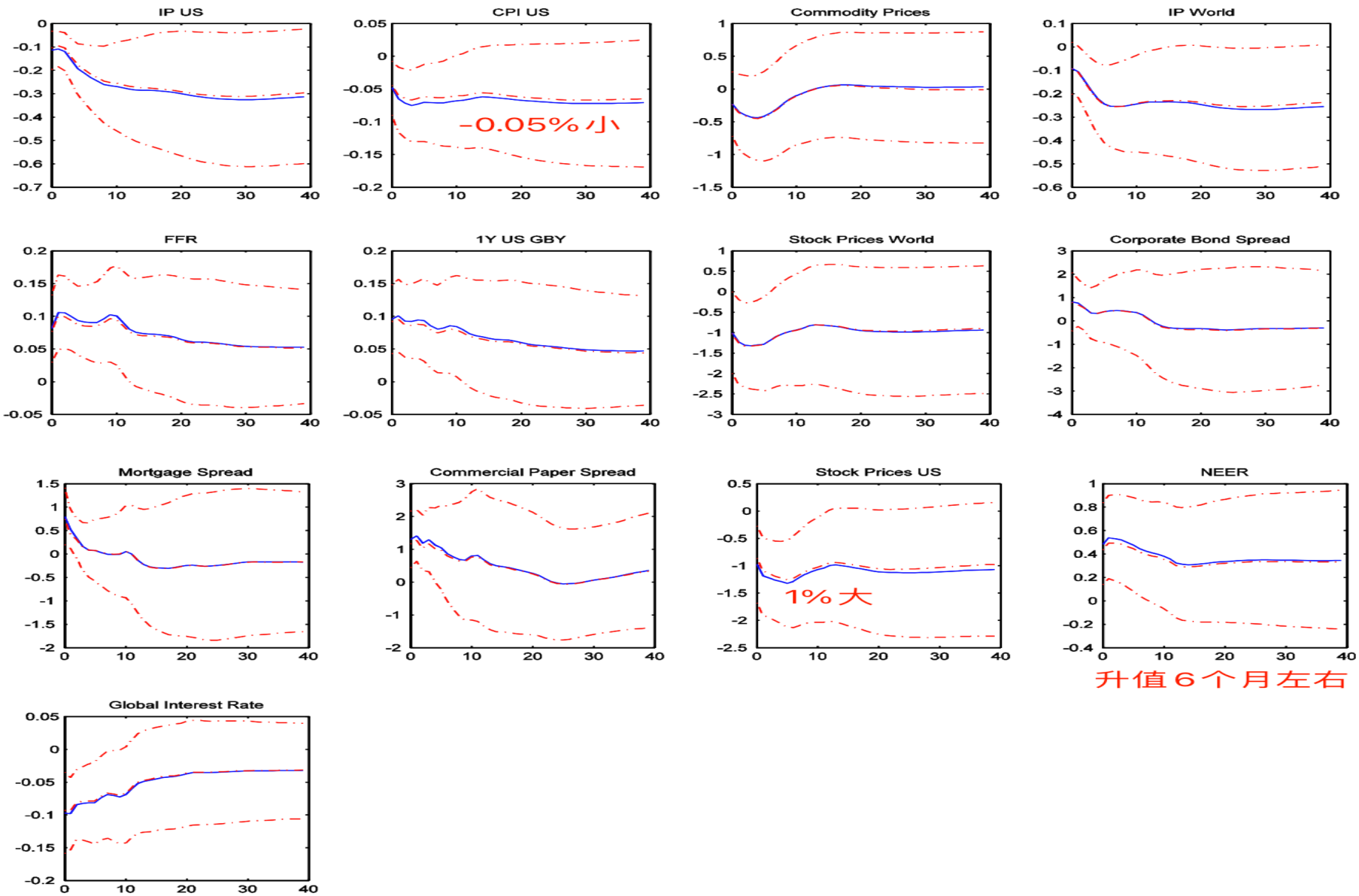


Fig. 1. IRFs from baseline BVAR estimated over the sample 1980–2013.

4. The domestic effects of US monetary policy shocks

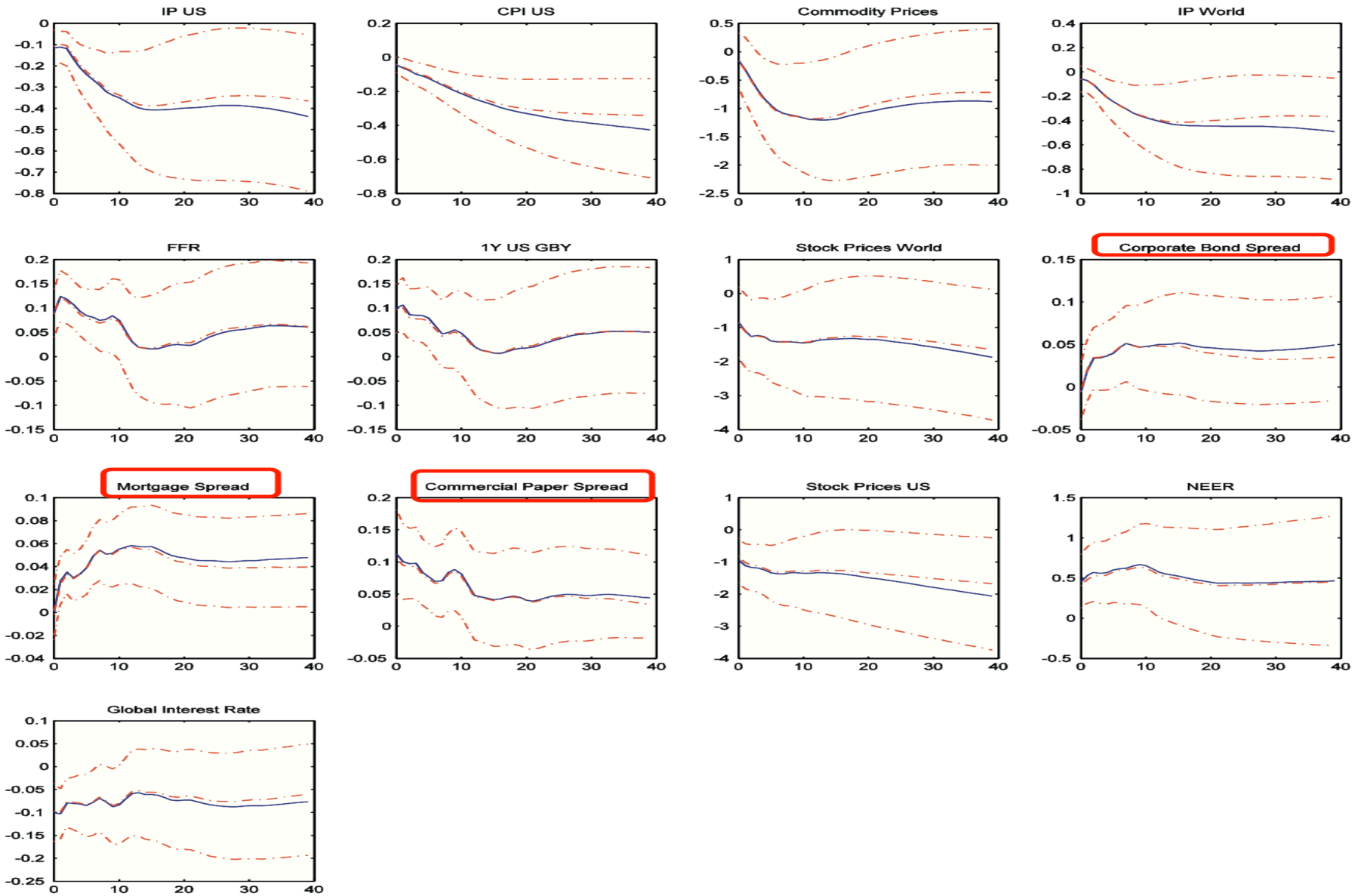


Fig. 2. IRFs from baseline BVAR estimated over the sample 1980–2008.

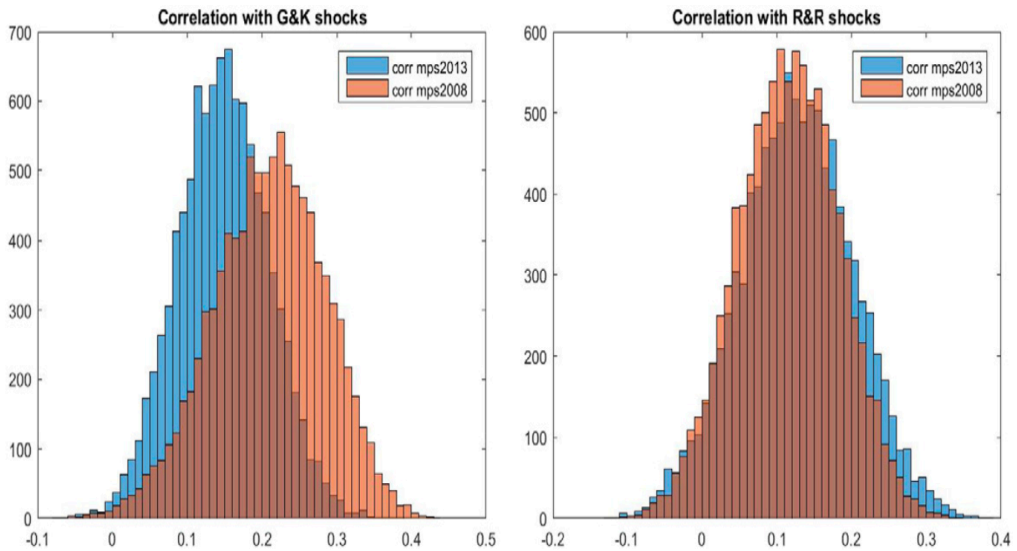


Fig. 3. Correlations between our estimated shocks and (i) Gertler and Karadi (2015) shocks, and (ii) updated Romer and Romer shocks from Barakchian and Crowe (2013).

Table 3
Correlations between Romer and Romer's (2004), Gertler and Karadi's (2015) and our shocks.[a]

Shocks	Mean	Median	Max	Min
R&R with MPS 2013	0.13	0.13	0.39	−0.13
R&R with MPS 2008	0.12	0.12	0.34	−0.12
G&K with MPS 2013	0.15	0.15	0.38	−0.07
G&K with MPS 2008	0.21	0.21	0.43	−0.06
G&K with R&R		0.19		

[a] The Romer and Romer's shocks are the updated series from Barakchian and Crowe (2013).

The VIX increase in response to a US monetary policy tightening.

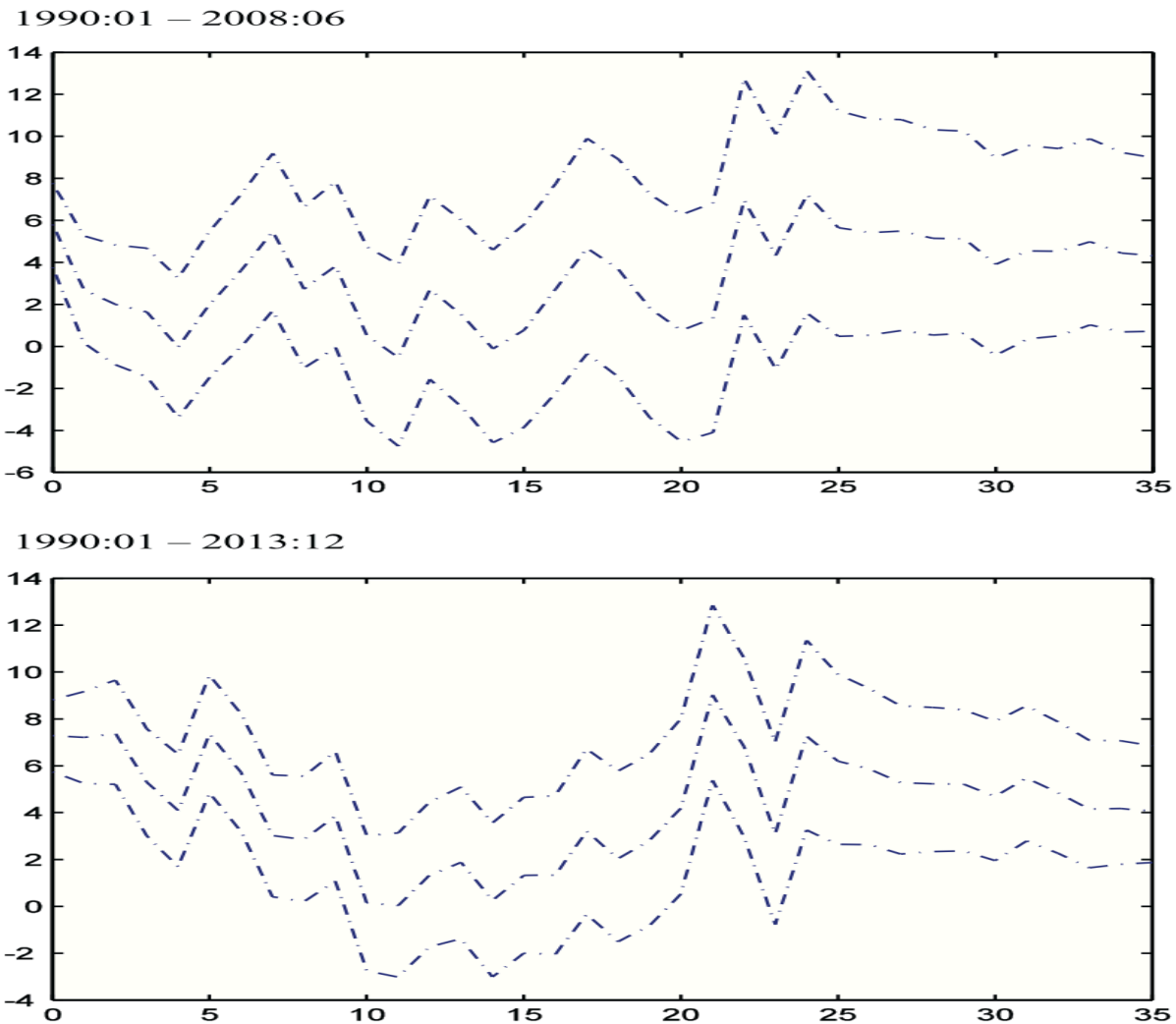


Fig. 4. VIX responses to US monetary policy shocks, monthly regressions.

4. The domestic effects of US monetary policy shocks

To summarize, these exercises together lend reasonable support to our benchmark identification and the effects of the resulting monetary policy shocks.

5. Evidence on the global transmission of US monetary policy shocks

- In the next subsection we provide a broad overview of the country specific responses to the US monetary policy shocks.
- In Section 5.2 we explore whether these responses have any commonality that can be attributed to shared **country characteristics**.

5. Evidence on the global transmission of US monetary policy shocks

a. Monthly regressions

- Emerging economies tend to experience **more volatile** macroeconomic effects.

5. Evidence on the global transmission of US monetary policy shocks

b. Quarterly regressions

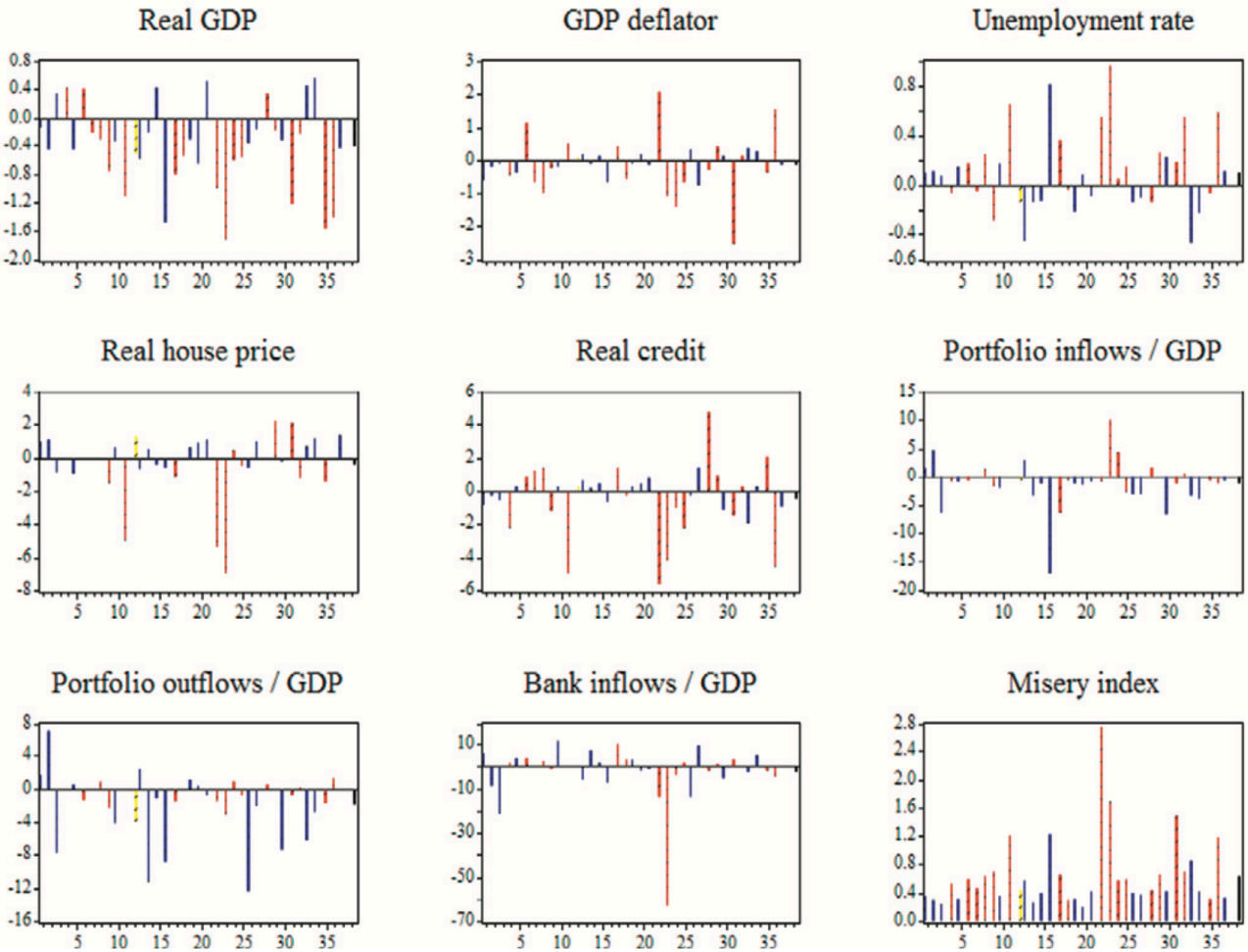
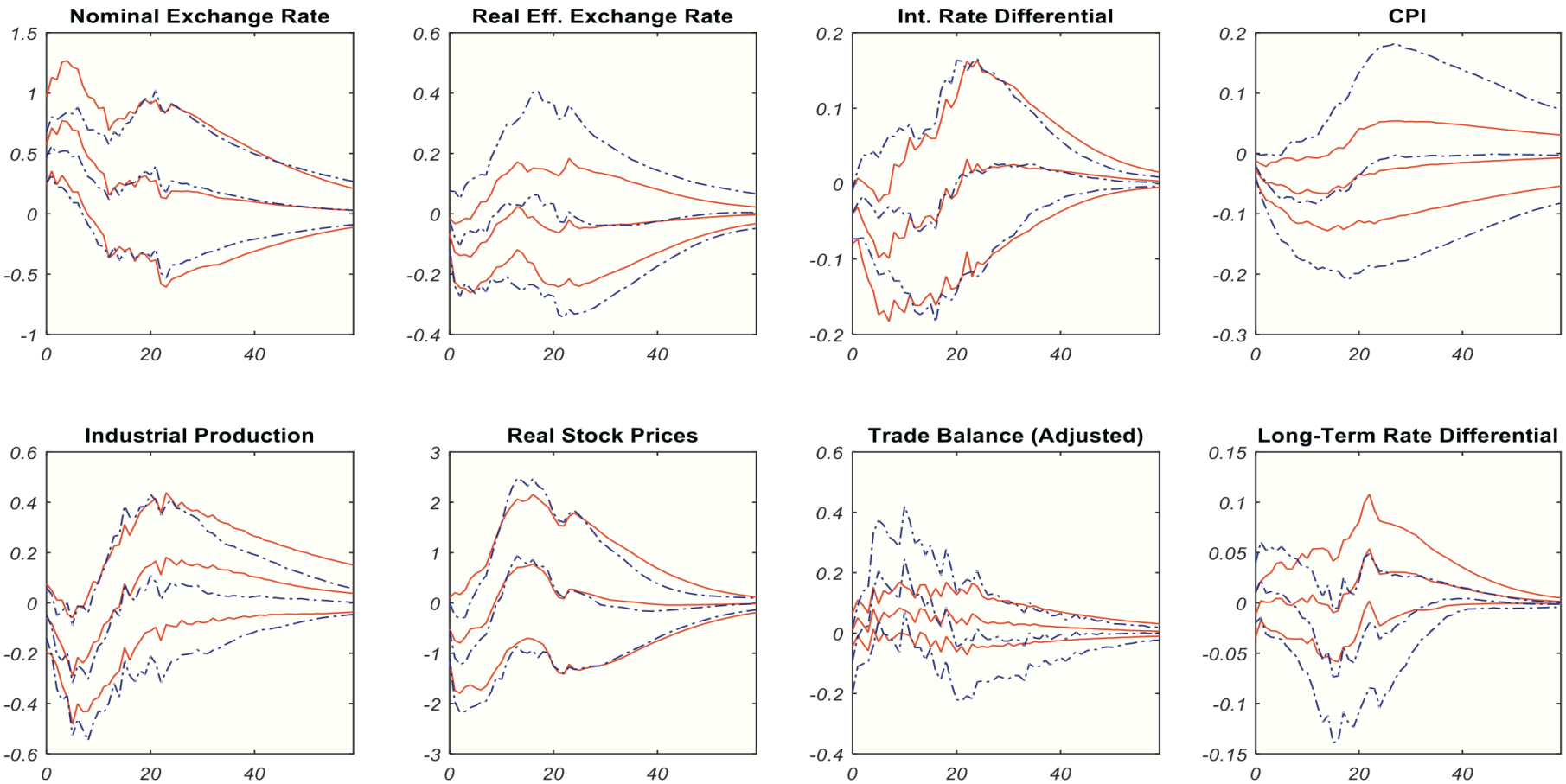


Fig. 5. Country-specific median peak impulse responses to a one standard deviation contractionary US monetary policy shock. a. Monthly regressions. b. Quarterly regressions. Sample period: 1980 - 2013. Note that we exclude inflation, the nominal exchange rate and the interest rate differential in Brazil as well as bank inflows into China due to very high values. Blue bars refer to advanced countries, red bars to emerging countries. The peak impulse response for the euro area is reported in yellow, and the overall country average in black to the very right.

5.2.1. Advanced vs. emerging countries

a. Monthly regressions



5.2.1. Advanced vs. emerging countries

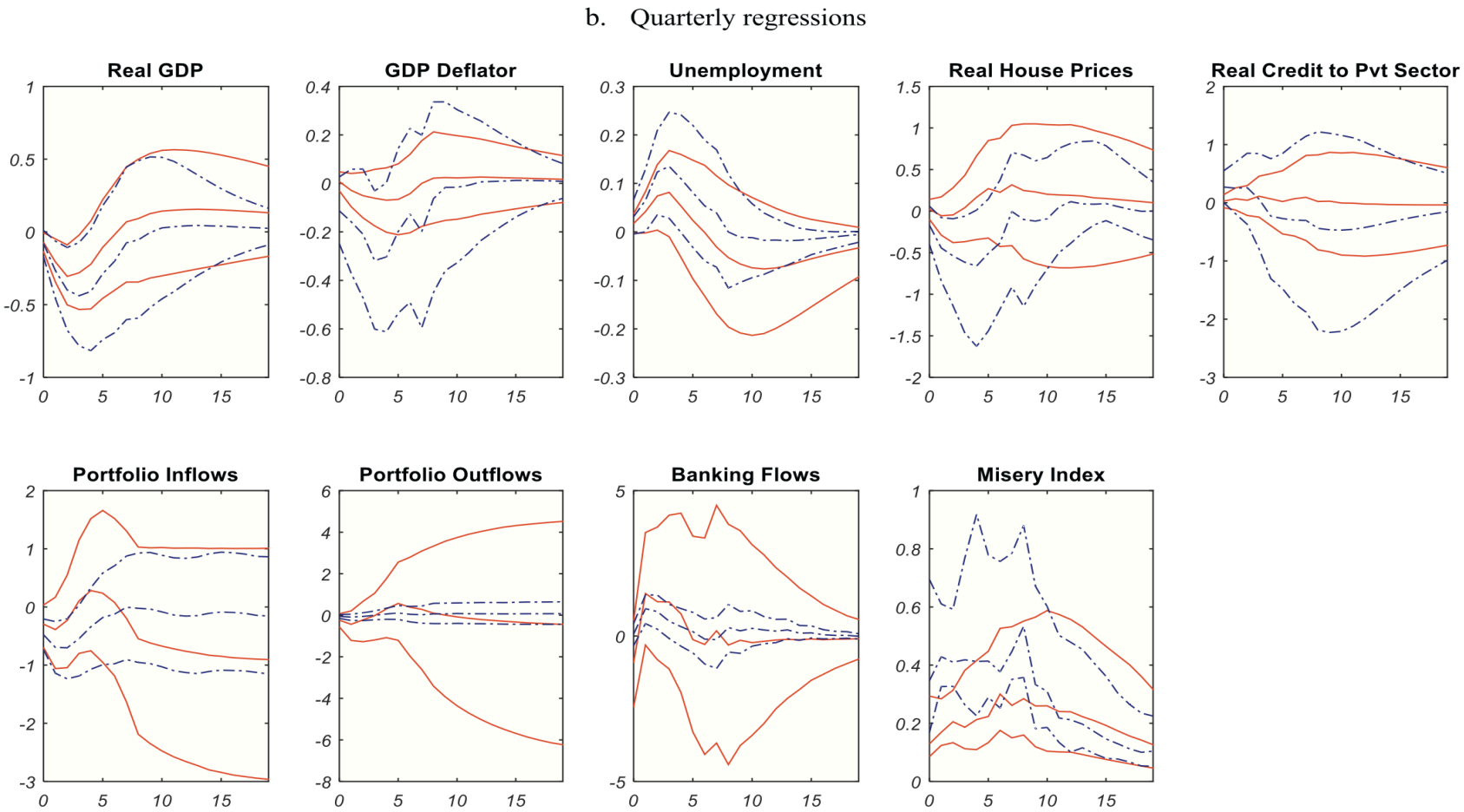
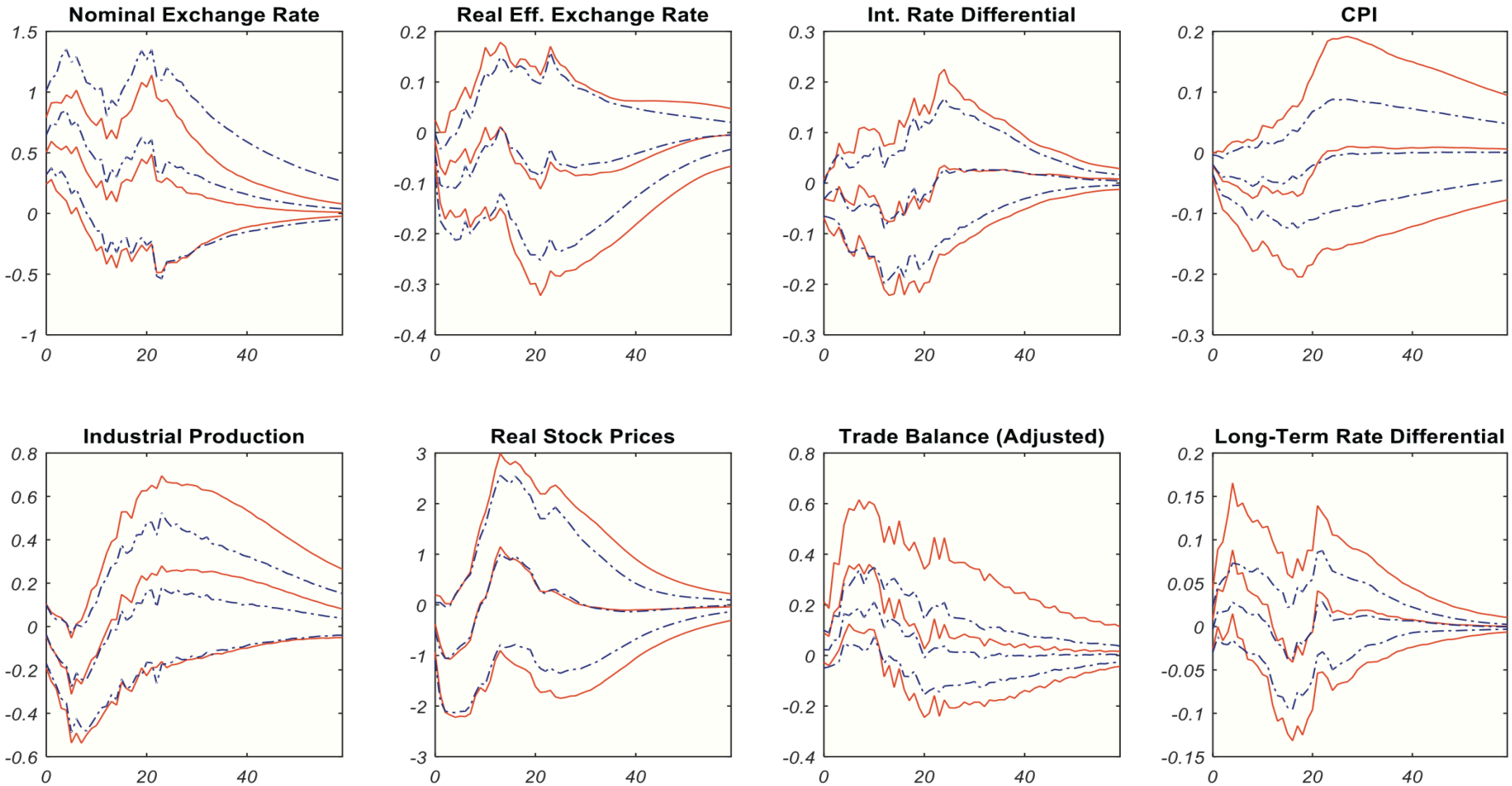


Fig. 6. Responses of advanced (solid red line) and emerging economies (dotted blue line) to US monetary policy shocks. a. Monthly regressions. b. Quarterly regressions.

5.2.2. capital mobility

a. Monthly regressions



5.2.2. capital mobility

b. Quarterly regressions

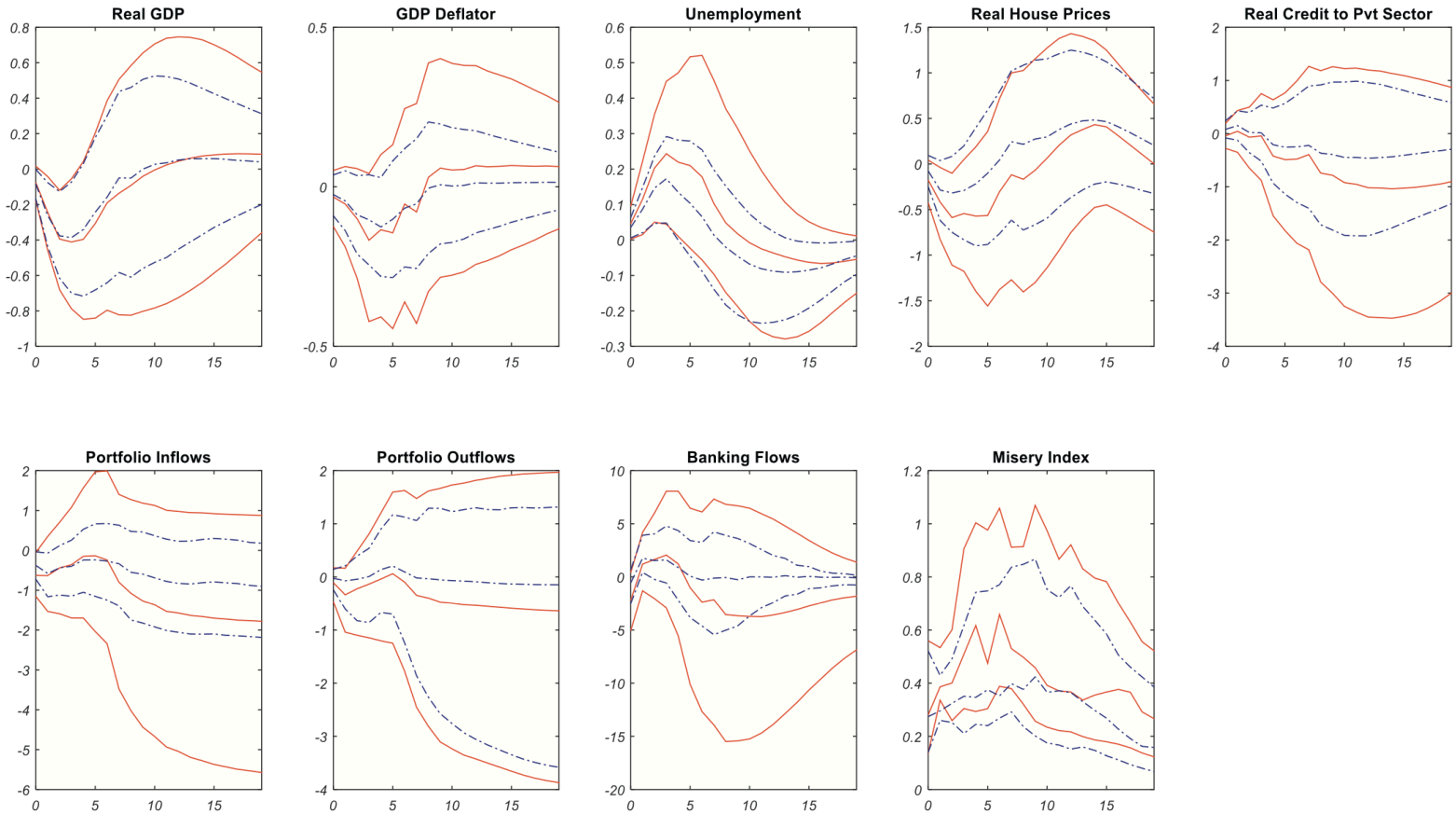


Fig. 7. Responses of EMEs with lower (solid red line) and higher capital mobility (dotted blue line) to US monetary policy shocks. a. Monthly regressions. b. Quarterly regressions.

5. Evidence on the global transmission of US monetary policy shocks

Our results so far...

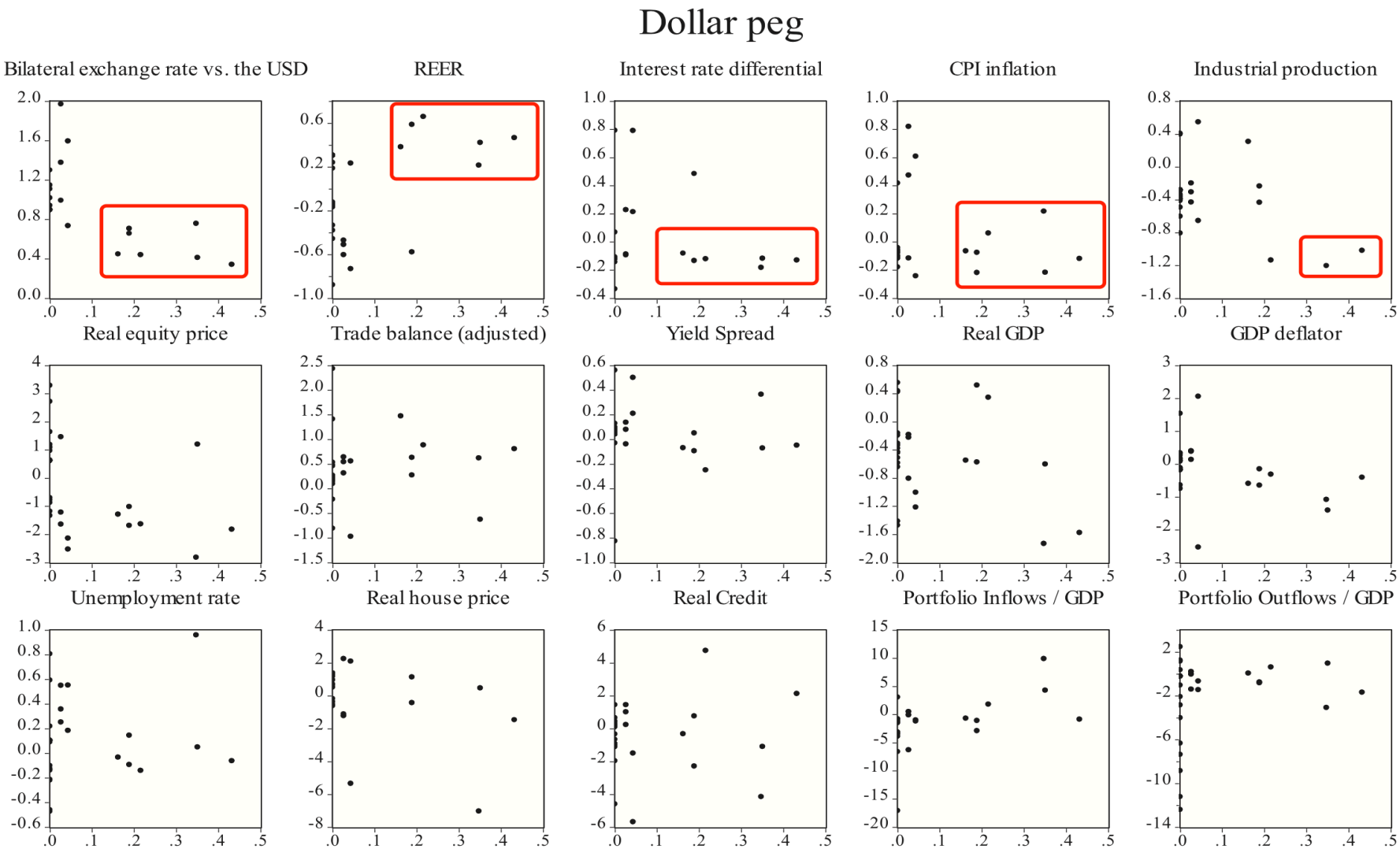
- however, are predicated on the assumption that country characteristics are constant across the sample and can be summarised as 0—1 dummies.
- Several country characteristics, such as differences in income levels, **are relatively persistent,** but not all of them are necessarily so.
- For example, there is some **time variation in the foreign exchange regime.**
- Some of the countries we classify as dollar pegs over the whole sample, in reality have had also spells of floating rates.
- This is the case of **India and Mexico,** for instance, which seem thus closer to an **intermediate** exchange rate regime over the whole sample.
- By the same token, several countries have an **intermediate degree of financial openness,** often the results of incremental measures of financial liberalization.
- Time variation in some characteristics can thus account for **the lack of sharp differences** between some groups, especially concerning the effects of the exchange rate regime.

Appendix–3.1. Country characteristics

Table 2
Country classifications[a].

Income level		Exchange rate regime		Capital openness		Dollar exposure		Trade openness		Commodity exporters	
Adavanced	Emerging	Floaters	Dollar pegs	More	Less	More	Less	More	Less	Exporers	Non-exporters
Australia	Brazil	Australia	China	Australia	Brazil	Belgium	Australia	Australia	Austria	Australia	Austria
Austria	Chile	Austria	India	Austria	Chile	Canada	Austria	Belgium	Czech Republic	Brazil	Belgium
Belgium	China	Belgium	Malaysia	Belgium	China	Chile	Brazil	Brazil	Denmark	Canada	China
Canada	Colombia	Brazil	Mexico	Canada	Colombia	China	Colombia	Canada	Estonia	Chile	Czech Republic
Denmark	Czech Republic	Canada	Philippines	Czech Republic	Greece	Czech Republic	Estonia	Chile	Finland	Colombia	Denmark
Finland	Estonia	Chile	Thailand	Denmark	Hungary	Denmark	Finland	China	France	Norway	Estonia
France	Hungary	Colombia		Estonia	India	France	Greece	Colombia	Greece	Russia	Finland
Germany	India	Czech Republic		Finland	Korea	Germany	Hungary	Germany	Hungary	South Africa	France
Greece	Latvia	Denmark		France	Malaysia	Japan	India	Japan	India		Germany
Italy	Lithuania	Estonia		Germany	Mexico	Korea	Italy	Korea	Italy		Greece
Japan	Malaysia	Finland		Italy	Norway	Malaysia	Latvia	Malaysia	Latvia		Hungary
Korea	Mexico	France		Japan	Philippines	Netherlands	Lithuania	Mexico	Lithuania		India
Netherlands	Philippines	Germany		Latvia	Poland	Norway	Mexico	Netherlands	Norway		Italy
Norway	Poland	Greece		Lithuania	Portugal	Russia	Philippines	Philippines	Poland		Japan
Portugal	Russia	Hungary		Netherlands	Russia	South Africa	Poland	South Africa	Portugal		Korea
Spain	South Africa	Italy		Spain	South Africa	Spain	Portugal	Sweden	Russia		Latvia
Sweden	Thailand	Japan		Sweden	Thailand	Sweden	Thailand	Thailand	Spain		Lithuania
UK	Turkey	Korea		UK	Turkey	UK	Turkey	UK	Turkey		Malaysia
		Latvia									Mexico
		Lithuania									Netherlands
		Netherlands									Philippines
		Norway									Poland
		Poland									Portugal
		Portugal									Spain
		Russia									Sweden
		South Africa									Thailand
		Spain									Turkey
		Sweden									UK
		Turkey									
		UK									

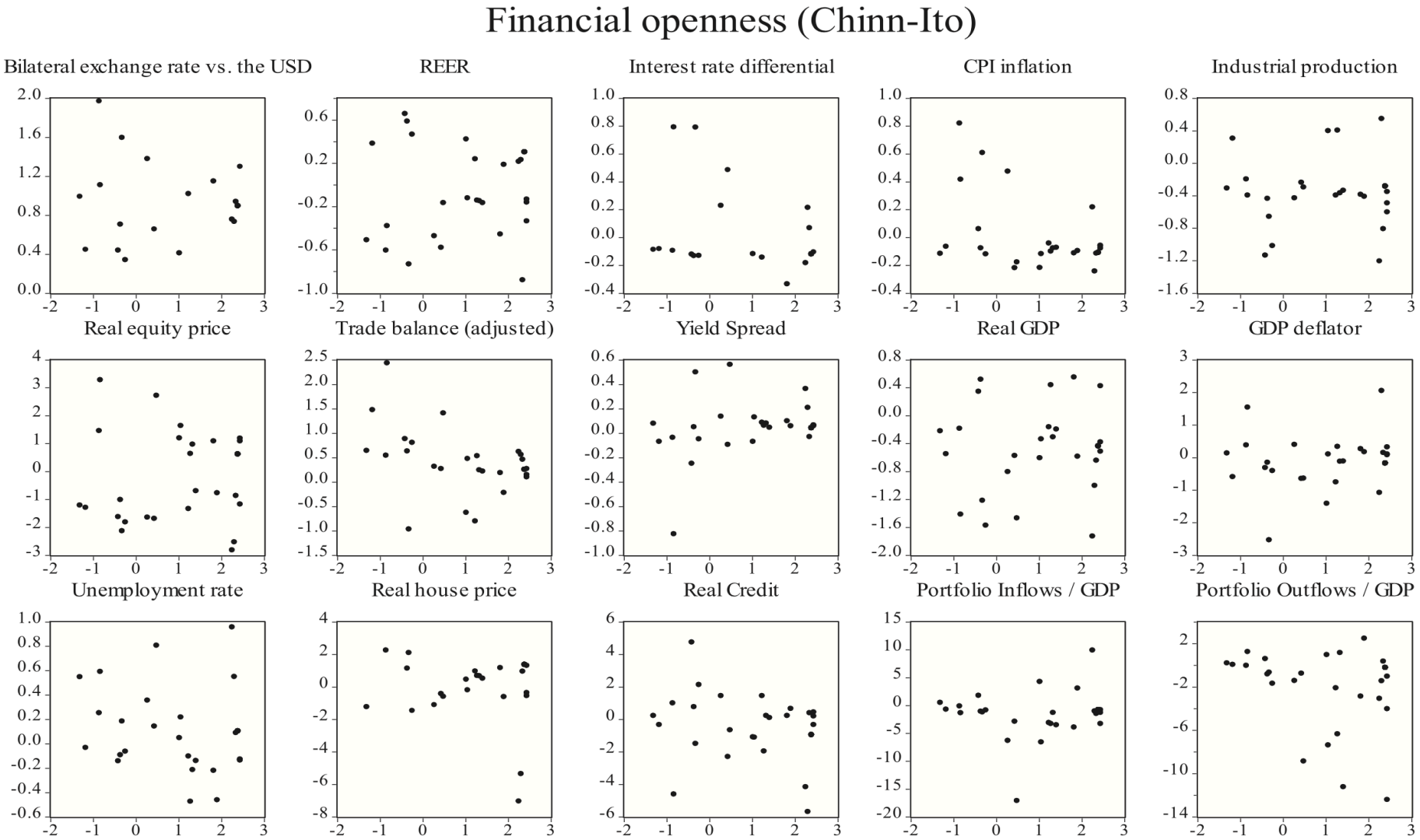
5. Evidence on the global transmission of US monetary policy shocks



Note: the scatter plots report peak impulse responses from the second stage regression (y axis) against the average country characteristic (dollar peg) over the whole sample (x axis).

Fig. 8. Country-specific median peak impulse response against average country characteristics.

5. Evidence on the global transmission of US monetary policy shocks



Note: the scatter plots report peak impulse responses from the second stage regression (y axis) against the average country characteristic (financial openness) over the whole sample (x axis).

Fig. 9. Country-specific median peak impulse response against average country characteristics.

6. Concluding remarks

A main policy implication of this finding is that

- conditional on monetary policy shocks, **neither** the exchange rate regime nor financial openness, at least the way we measure them, **appear to matter much for the international transmission of US monetary policy. (无关紧要)**
- we do not find compelling evidence that **capital controls** may provide an effective protection against US monetary spillovers.

Appendix–SVAR with sign

The second approach, proposed in Uhlig (2005), is called the **penalty function method**. In particular, the latter proposes the minimization of a penalty function given by:

$$b(x) = \begin{cases} x & \text{if } x \leq 0 \\ 100x & \text{if } x > 0 \end{cases} \tag{9}$$

which penalizes positive responses in linear proportion, and rewards negative responses in linear proportion, albeit at a slope 100 times smaller than those on positive sides.

The steps involved in this algorithm can be summarized as follows:

1. Run an unrestricted VAR in order to get $\widehat{\mathbf{B}}$ and $\widehat{\mathbf{\Sigma}}$.
2. Randomly draw $\bar{\mathbf{B}}_T$ and $\mathbf{S}_T$ from the posterior distributions.
3. Extract the orthogonal innovations from the model using a Cholesky decomposition.
4. Calculate the resulting impulse responses from Step 3.
5. Minimize the penalty function with respect to an orthogonal impulse vector α.
6. Multiply the responses from Step 4 by α.

Appendix–3.1. Country characteristics

Table 1
Average sample values of country characteristics.

Country	Lane and Shambaugh (2010) dollar peg	Chinn and Ito (2006) capital openness	Benetrix et al. (2015) dollar exposure	Trade exposure
Australia	0	1.422	51,771	4,09%
Austria	0	1.903	42,402	2,30%
Belgium	0	1.713	97,406	9,41%
Brazil	0	−1.147	34,089	3,71%
Canada	0.147	2.439	97,251	38,30%
Chile	0.059	−0.325	76,571	8,64%
China	0.618	−1.318	35,067	4,93%
Colombia	0	−1.149	44,366	8,29%
Czech Republic	0	1.559	33,450	2,58%
Denmark	0	1.719	69,907	2,88%
Estonia	0	2.390	18,112	3,11%
Finland	0	1.903	46,878	2,95%
France	0	1.410	46,067	2,57%
Germany	0	2.439	39,907	3,72%
Greece	0	0.487	14,873	1,13%
Hungary	0	0.272	24,311	2,53%
India	0.176	−1.169	24,344	2,24%
Italy	0	1.334	26,168	2,35%
Japan	0	2.348	46,915	4,54%
Korea	0.147	−0.361	41,999	11,56%
Latvia	0.045	2.307	24,785	1,31%
Lithuania	0.364	2.258	23,753	2,42%
Malaysia	0.353	1.025	68,766	22,54%
Mexico	0.147	0.435	44,349	27,30%
Netherlands	0	2.439	95,219	5,82%
Norway	0	1.237	72,906	3,20%
Philippines	0.147	−0.409	50,386	12,53%
Poland	0	−0.854	26,576	1,15%
Portugal	0	1.056	18,342	2,35%
Russia	0.045	−0.320	60,264	2,31%
South Africa	0	−1.309	30,956	4,28%
Spain	0	1.279	22,996	1,93%
Sweden	0	1.821	68,828	3,95%
Thailand	0.382	−0.245	41,979	10,94%
Turkey	0	−0.827	31,094	2,02%
UK	0	2.390	207,213	4,47%