International Strategic Spillovers of Monetary Policy

Juan Antonio Montecino
Columbia University

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Introduction: Strategic Spillovers

Research Question

Does monetary policy create multilateral externalities? If so, how do countries react to these spillovers?

This Paper

- Study international transmission of monetary policy through global financial networks
- Spatial/network model of strategic interdependence
- Examine role of capital account & exchange rate policies

Results

- Empirical evidence of strong strategic complementarities
- Implies amplification in equilibrium
- Evidence that capital controls increase policy autonomy
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Background
Background

Debate on international spillovers

- Concern with externalities from self-oriented macro policy
- E.g. Currency Wars debate
- Huge literature on macro effects of US m-policy:
  - Output spillovers (e.g. Georgiadis, 2016)
  - Capital flows (e.g. Bruno and Shin, 2015)
  - Exchange rate (e.g. Chen et al, 2016)
  - Exports (e.g. Lin and Ye, 2017)

“Impossible Trinity” debate

- Capital mobility, fixed XR, monetary autonomy → choose two!
- Evidence on Mundellian Trilemma
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Strategic interactions?

- Little attention on how domestic policy reacts to neighbors’ policy
- Endogenous reactions may **amplify initial spillover**
- Theoretical literature: *international policy coordination*
  - First-wave: Niehans (1968), Hamada (1979)
  - Contemporary: Korinek (2016), Blanchard (2016)

My contribution

- First paper to study *contemporaneous* strategic reactions
- Evidence that higher-order network effects matter
- Combination implies strong amplification in equilibrium
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Taxonomy of previous studies

(a) “Base country” studies

- Periphery countries linked to base (e.g. through peg)
- Base country is exogenous

(b) “Bilateral” studies

- Each bilateral spillover estimated individually
- Typically, bilateral VARs
This paper

Spatial / Network Model

(a) Base-country studies: Periphery countries (1) through (4) are connected to base countries (e.g. through a currency peg). Base countries are assumed to be exogenous. Examples include Frankel et al. (2004), Shambaugh (2004).

(b) Bilateral studies: Examine the impact of a (possibly identified) monetary policy shock in one large country, typically the U.S., on a set of macroeconomic and financial outcome variables in foreign countries. The spillovers are estimated for each country pair separately. Examples include Bluedorn and Bowdler (2011), Canova (2005), and Miniane and Rogers (2007).

(c) SAR / Network Model: General structure of connections between countries, including bi-directional causality (e.g. between countries (1) and (6)). Monetary policy is allowed to be endogenous in every country.

Figure 1: Taxonomy of Monetary Policy Spillover Specifications

- General structure of linkages between countries
- M-policy is endogenous in every country
- Possibility of third-country / higher-order effects
Consider a central bank in country $i$ with the following loss function:

$$\min_{r_i} \mathcal{L}_i = \frac{1}{2} \sum_{k=1}^{K} \alpha_{ik} (Y_{ik} - \bar{Y}_{ik})^2$$

subject to

$$Y_{ik} = Y_{ik}(r, X) \quad \text{for } k = 1, 2, \ldots, K$$

- Policy rate: $r = \{r_1, r_2, \ldots, r_N\}$
- Macro variable: $Y_{ik}$ (e.g. employment)
- Exogenous observable: $X$
- **Macro spillover**: $\partial Y_{ik}/\partial r_\ell \neq 0$
Conceptual Framework

First order condition for $r_i$:

$$\sum_{k=1}^{K} \alpha_{ik} \left( Y_{ik} - \bar{Y}_{ik} \right) \frac{\partial Y_{ik}}{\partial r_i} = 0$$

Implies Nash / Cournot equilibrium:

$$r_i^* = f_i(\{r_j^*\}_{j \neq i}, X) \quad \text{for all } i = \{1, 2, \ldots, N\}$$

Note:

- Domestic policy rate depends on foreign rates and domestic $X$
- **Strategic spillover**: $\partial r_i / \partial r_\ell \neq 0$
Econometric Model

Consider the following $N$-country Network Model:

$$ r_{it} = \delta \sum_{j=1}^{N} w_{ij} r_{jt} + \beta X_{it} + u_{it} $$

- **Spatial lag:** $\bar{r}_{it} = \sum_{j=1}^{N} w_{ij} r_{j}$
- **Weighting Matrix:** $W$
- **Predetermined macro variables** $X$
- Clearly, foreign rates $r_{j \neq i}$ are endogenous (i.e. $\mathbb{E}\{Wru\} \neq 0$)
- OLS estimate of $\delta$ will be inconsistent
Identification Strategy

Reduced form solution:

\[ r_t = (I - \delta W)^{-1}\beta X_t + (I - \delta W)^{-1}u_t \]

Neighbors’ monetary policy:

\[ E\{Wr_t|X_t\} = W\beta X_t + \delta W^2\beta X_t + \delta^2 W^3\beta X_t + \ldots \]

- where \((I - \delta W)^{-1} = \sum_{k=0}^{\infty} \delta^k W^k\)
- Assuming \(E(u|X) = 0\) holds
- \(WX, W^2X, W^3X \ldots\) are valid instruments
- **Intuition:** use neighbors’ characteristics to instrument foreign monetary policy
Data and Estimation Details

Data

- Sample of 33 advanced and EMEs
- Quarterly frequency, 1999Q1 to 2016Q4
- Mix of narrative policy interest rates and shadow rates
- Large set of macro variables
- Forecast data to deal with expectational effects
- Stationarity properties

Estimation

- Mostly Two-step GMM
- Control functions for non-linear effects
- Inference: Driscoll and Kraay (1998) standard errors
- Robust to heteroskedasticity, temporal and cross-sectional correlation
(a) Gross bilateral bank positions

These are depicted in Figure 2. As a robustness check, I consider additional alternative weighting matrices, and bilateral foreign asset positions, obtained from the BIS and Hobza and Zeugner (2014), respectively. Rate. In what follows I use weighting matrices built with data on gross bilateral bank financial positions, including one constructed from gross bilateral trade flows. Naturally, a key consideration is the network structure of interlinkages between economies, which must be specified a priori. See Appendix D for more details.

(b) Gross bilateral investment positions

All matrices are row-normalized such that the denominator is the row-sum at time $t$. Finally, all weighting matrices are lagged in order to minimize potential endogeneity concerns.

Note: $w_{ijt}$.
First-Stage

(a) 1st-order lag
(b) 2nd-order lag
(c) 3rd-order lag

- Growth forecast errors: $FEG$
- Instrument $Wr$ using spatial lags of $FEG$
### Strategic spillovers: $\hat{\delta}$

**Weighting Matrix ($W$):** Bilateral bank positions

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>First-Stage Results</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$W \cdot FEG$</td>
<td>0.122***</td>
<td>0.119***</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td>(0.040)</td>
<td>(0.029)</td>
<td></td>
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</tr>
<tr>
<td>$W^2 \cdot FEG$</td>
<td>0.215***</td>
<td>0.230***</td>
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<tr>
<td></td>
<td>(0.065)</td>
<td>(0.054)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$W^3 \cdot FEG$</td>
<td>0.276***</td>
<td>0.281***</td>
<td></td>
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<tr>
<td></td>
<td>(0.078)</td>
<td>(0.063)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Second-Stage Results</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$W_r$</td>
<td>0.708***</td>
<td>0.823**</td>
<td>0.782***</td>
<td>0.814***</td>
<td>0.778***</td>
<td>0.836***</td>
</tr>
<tr>
<td></td>
<td>(0.214)</td>
<td>(0.338)</td>
<td>(0.242)</td>
<td>(0.240)</td>
<td>(0.300)</td>
<td>(0.265)</td>
</tr>
</tbody>
</table>

**Observations:**
- (1) 1008
- (2) 1008
- (3) 1008
- (4) 928
- (5) 932
- (6) 937

**Kleibergen-Paap F-stat:**
- (1) 9.135
- (2) 10.833
- (3) 12.384
- (4) 16.492
- (5) 17.801
- (6) 19.356

**Anderson-Rubin test ($\chi^2$):**
- (1) 3.945
- (2) 4.835
- (3) 5.018
- (4) 5.393
- (5) 4.295
- (6) 4.762

**p-value:**
- (1) 0.047
- (2) 0.028
- (3) 0.025
- (4) 0.020
- (5) 0.038
- (6) 0.029

- **$X$:** lagged growth & inflation forecast errors, RER appreciation
- **Global Financial Crisis dummy**
- **2S-GMM, Driscoll-Kraay standard errors**
Anatomy of a spillover: **USA**
Anatomy of a spillover: **USA**
Anatomy of a spillover: USA
Anatomy of a spillover: *Eurozone*
Anatomy of a spillover: *Eurozone*
Anatomy of a spillover: *Eurozone*
Anatomy of a spillover: **Eurozone**
Comparison of Spillover Specifications

### Average spillover across alternative models

<table>
<thead>
<tr>
<th></th>
<th>United States</th>
<th>United Kingdom</th>
<th>Eurozone</th>
<th>Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$dr_i/dr_B$</td>
<td>$SE$</td>
<td>$dr_i/dr_B$</td>
<td>$SE$</td>
</tr>
<tr>
<td>(1) Base-country</td>
<td>0.175***</td>
<td>(0.056)</td>
<td>0.223**</td>
<td>(0.098)</td>
</tr>
<tr>
<td>Network model</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2) OLS</td>
<td>0.117**</td>
<td>(0.057)</td>
<td>0.099*</td>
<td>(0.055)</td>
</tr>
<tr>
<td>(3) 2S-GMM</td>
<td>0.325***</td>
<td>(0.096)</td>
<td>0.335***</td>
<td>(0.121)</td>
</tr>
<tr>
<td>Higher-order effects</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(4) Avg. multiplier</td>
<td>1.384***</td>
<td>(0.106)</td>
<td>1.977***</td>
<td>(0.284)</td>
</tr>
<tr>
<td>(5) Share of total</td>
<td>0.277***</td>
<td>(0.055)</td>
<td>0.494***</td>
<td>(0.073)</td>
</tr>
</tbody>
</table>

- Naive “base-country” specification:
  
  $$r_{it} = \gamma_B r_{Bt} + \beta X_{it} + u_{it}$$

- Spillover estimates $\hat{\gamma}_B$ are biased!
Partial and General Equilibrium Effects

Consider the network model:

$$r = \delta W r + \beta X + u$$

- Let $B = (I - \hat{\delta}W)^{-1}$
- Let $A_\ell$ denote the $\ell$-th column of a matrix $A$
- Suppose there’s a shock $du_\ell$ to country $\ell$’s policy rate...

Direct / PE effects:

$$dr_{PE} = \hat{\delta} W_\ell du_\ell$$

Indirect / GE effects:

$$dr_{GE} = B_\ell du_\ell$$
Partial and General Equilibrium Effects

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Partial and General Equilibrium Effects

USA → ROW

GBR → ROW

EUR → ROW

Weighting matrix ($W$):
Gross bilateral bank positions
Capital Account and Exchange Rate Policies

\[ r_{it} = (\delta_0 + \theta K_{it}) \cdot \bar{r}_{it} + \beta X_{it} + u_{it} \]

- Heterogeneity / non-linearities captured by interactions
- \( \theta \) measures reaction difference relative to base level \( \delta_0 \)
- \( K \): Capital controls & reserve accumulation
- *Intuition*: Can interventions provide insulation?
# Capital Account and Exchange Rate Policies

Table 5: Strategic spillovers under capital account and exchange rate policies

<table>
<thead>
<tr>
<th>Weighting Matrix (W): Gross bilateral bank positions</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( Wr )</td>
<td>0.817***</td>
<td>0.867***</td>
<td>0.876***</td>
<td>0.835***</td>
<td>0.878***</td>
<td>0.890***</td>
</tr>
<tr>
<td></td>
<td>(0.170)</td>
<td>(0.174)</td>
<td>(0.150)</td>
<td>(0.164)</td>
<td>(0.172)</td>
<td>(0.150)</td>
</tr>
<tr>
<td>( Wr \cdot K_{CI} )</td>
<td>-0.589**</td>
<td></td>
<td>-0.622**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.285)</td>
<td></td>
<td>(0.277)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( Wr \cdot K_{SCH} )</td>
<td>-0.721**</td>
<td></td>
<td>-0.733***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.298)</td>
<td></td>
<td>(0.269)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( Wr \cdot K_{IN} )</td>
<td></td>
<td>-0.952***</td>
<td></td>
<td>-0.973***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.321)</td>
<td></td>
<td>(0.331)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( Wr \cdot RES )</td>
<td></td>
<td>-0.032</td>
<td>-0.025</td>
<td>-0.027</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.032)</td>
<td>(0.021)</td>
<td>(0.020)</td>
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</tr>
</tbody>
</table>

Closed capital account spillover

| \( \hat{\delta}_0 + \hat{\theta}_1 \) | 0.229 | 0.145 | -0.076 | 0.213 | 0.145 | -0.084 |
|                                       | (0.240) | (0.228) | (0.293) | (0.238) | (0.200) | (0.291) |

Observations | 952 | 884 | 884 | 952 | 884 | 884 |

Note: This table reports control function estimates of model (13). \( K_{CI}, K_{SCH}, \) and \( K_{IN} \) refer, respectively, to the inverse Chinn-Ito index of capital mobility, the Schindler index of capital controls, and the Schindler index of controls on capital inflows. \( RES \) denotes changes in international reserves as a percent of GDP. The endogenous spatial lag of monetary policy is instrumented using the third-order spatial lag of GDP growth forecast errors. Bootstrap standard errors with 500 repetitions in parentheses. ⋆⋆⋆\( p<0.01, \) ⋆⋆\( p<0.05, \) ⋆\( p<0.1. \)

17 In principle, one could also include interaction terms for an index of the exchange rate regime, such as the de facto classification provided by Ilzetski, Reinhart, and Rogo (IRR) (Ilzetzki et al., 2017). One problem with using the IRR classification is that very few countries in my sample are classified as “floating” regimes and there is limited variation across time. Additionally, it is not obvious how to handle the case of the Eurozone, which is a currency union from the perspective of its member countries but is arguably a flexible exchange regime vis-a-vis the rest of the world. Finally, it is often the case that countries classified as having a flexible exchange rate regime nevertheless intervene actively in foreign exchange markets.
Capital Account and Exchange Rate Policies

Takeaways...

- Spillover effect is lower in countries with capital controls
- *Interpretation:* Insulation against foreign shocks
- ⇒ Increase in policy autonomy

Other heterogeneity?

- Financial integration: *increase* spillovers
- Inflation targeting: *no effect*
- Business cycle: *mixed*
Capital Account and Exchange Rate Policies

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Dynamics

How do countries react *over time*?

- Estimate impulse response using *local projection* (Jordà, 2005)
- IV methods to identify endogenous effects
- Consider the following local projection:

\[
\mathbf{r}_{t+h} = \delta_h \mathbf{W} r_t + \beta_h \mathbf{X}_t + \mathbf{u}_t
\]

- Estimate for each *horizon* \( h = \{1, 2, \ldots, H\} \)
- Coefficient \( \hat{\delta}_h \) measures the impulse response after \( h \) quarters
Dynamics

**Impulse response function**

- Horizon vs. IRF
- 99 C.I., 95 C.I., 90 C.I.

**Cumulative response**

- Horizon vs. Cumulative response
- 99 C.I., 95 C.I., 90 C.I.

Extras
Dynamics: Capital Controls

**Open capital account**

**Closed capital account**

- **IRF**
- **99% C.I.**
- **95% C.I.**
- **90% C.I.**

```
 extras
```
Robustness Exercises

1. **Alternative specifications/estimators**
   - Network structures ($W$)
   - Overidentified models
   - CUE estimator

2. **High-Dimensional / LASSO Methods**
   - Data driven selection of 1st stage instruments
   - High-dimensional controls

3. **Placebo Networks**
   - Assess role of $W$ misspecification by randomizing network
   - Probability that result is driven by misspecification is low
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Thank You :)
High-Dimensional Instruments

\[ E\{ Wr_t | X_t \} = W \beta X_t + \delta W^2 \beta X_t + \delta^2 W^3 \beta X_t + \ldots \]

- In principle, there are an infinite number of valid instruments
- Rule of thumb: use \( WX \), \( W^2 X \), and \( W^3 X \)
- Alternative: LASSO shrinkage estimator
- **Chernozukhov, Hansen, Splinder (2015)** – model for high-dimensional IVs
- Post-LASSO 2SLS / GMM: use selected instruments in standard estimator
### CHS / Post-LASSO GMM Estimates of $\hat{\delta}$

<table>
<thead>
<tr>
<th>Penalty Loading Cluster: Year Country</th>
<th>LASSO</th>
<th>S-LASSO</th>
<th>LASSO</th>
<th>S-LASSO</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Estimator:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
</tr>
<tr>
<td>(a) Weighting Matrix ($W$):</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Orthogonalized 2SLS</strong></td>
<td>0.571*</td>
<td>0.437</td>
<td>0.765***</td>
<td>0.663**</td>
</tr>
<tr>
<td></td>
<td>(0.310)</td>
<td>(0.267)</td>
<td>(0.258)</td>
<td>(0.286)</td>
</tr>
<tr>
<td><strong>Post-LASSO GMM</strong></td>
<td>0.667**</td>
<td>0.475**</td>
<td>0.557***</td>
<td>0.530***</td>
</tr>
<tr>
<td></td>
<td>(0.331)</td>
<td>(0.207)</td>
<td>(0.119)</td>
<td>(0.140)</td>
</tr>
<tr>
<td>Anderson-Rubin Weak Inst. Test ($\chi^2$)</td>
<td>2.863</td>
<td>3.007</td>
<td>7.967</td>
<td>7.037</td>
</tr>
<tr>
<td>AR (p-value)</td>
<td>0.091</td>
<td>0.083</td>
<td>0.019</td>
<td>0.030</td>
</tr>
<tr>
<td>(b) Weighting Matrix ($W$):</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td><strong>Orthogonalized 2SLS</strong></td>
<td>0.983***</td>
<td>0.790**</td>
<td>1.087***</td>
<td>1.069***</td>
</tr>
<tr>
<td></td>
<td>(0.390)</td>
<td>(0.372)</td>
<td>(0.339)</td>
<td>(0.361)</td>
</tr>
<tr>
<td><strong>Post-LASSO GMM</strong></td>
<td>1.058***</td>
<td>0.767***</td>
<td>0.588***</td>
<td>0.724***</td>
</tr>
<tr>
<td></td>
<td>(0.328)</td>
<td>(0.195)</td>
<td>(0.174)</td>
<td>(0.181)</td>
</tr>
<tr>
<td>Anderson-Rubin Weak Inst. Test ($\chi^2$)</td>
<td>5.902</td>
<td>6.745</td>
<td>8.093</td>
<td>10.365</td>
</tr>
<tr>
<td>AR (p-value)</td>
<td>0.015</td>
<td>0.009</td>
<td>0.017</td>
<td>0.006</td>
</tr>
</tbody>
</table>

Note: Orthogonalized 2SLS refers to the CHS “post-regularization” estimator proposed by Chernozukhov, Hansen, and Splinder (2015). Post-LASSO GMM refers to two-step GMM using the instruments and controls selected by the CHS estimator. S-LASSO refers to the square-root LASSO estimator.
Placebo Network Tests

- How likely would it be to obtain $\hat{\delta}$ from a *random* network?
- $W$ misspecification problem
  - Measurement error?
  - Incorrect network?
- Direction of bias is not obvious

Randomized Placebo Networks:

1. Reshuffle weight matrix $W$ to obtain $\tilde{W}$
2. Construct placebo spatial lag of the policy rate $\tilde{r} = \tilde{W}r$
3. Estimate $r = \delta \tilde{r} + \beta X + u$ to obtain placebo spillover $\tilde{\delta}$
4. Repeat $P$ times
In this section, I report results from a “placebo exercise” intended to shed light on the resilience of the estimation algorithm:

1. Reshape weight matrix $W$ to obtain $\tilde{W}$
2. Construct placebo spatial lag of the policy rate $\tilde{r} = \tilde{W}r$

Placebo Network Tests

Distribution of placebo spillovers

(a) Common factors
(b) Time FE

Panel (a) considers a specification controlling for common factors, while the specification in panel (b) includes year fixed effects. The networks are randomized by misspecification of the network.

To understand this potential bias, I draw a large sample of random “placebo networks” and combine these with the observed data to obtain placebo estimates of the spillover coefficients. The networks are randomized by misspecification of the weighting matrix.

This is potentially important for two reasons. First, the distribution of edges. The reshaping of the links in the observed matrix of bilateral financial stocks so as to preserve the original distribution can then be used to construct a placebo spatial lag.

More generally, it would be reassuring to be able to place approximate bounds on the direction and magnitude of the bias introduced by misspecification of the network. Although I have argued that bilateral financial linkages and trade are the relevant linkages for the transmission of international spillovers, it is possible to conceive of alternative weighting schemes.
### Data: Summary statistics and variable definitions

<table>
<thead>
<tr>
<th>Variable Description</th>
<th>Mean</th>
<th>Sd</th>
<th>Min</th>
<th>Min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Policy rate (first-difference)</td>
<td>-0.002</td>
<td>0.012</td>
<td>-0.220</td>
<td>0.130</td>
</tr>
<tr>
<td>Real GDP Growth (Y-o-Y)</td>
<td>0.031</td>
<td>0.032</td>
<td>-0.155</td>
<td>0.187</td>
</tr>
<tr>
<td>Inflation rate</td>
<td>0.038</td>
<td>0.056</td>
<td>-0.025</td>
<td>0.774</td>
</tr>
<tr>
<td>Real exchange rate appreciation</td>
<td>0.001</td>
<td>0.083</td>
<td>-0.599</td>
<td>0.291</td>
</tr>
<tr>
<td>Stock Market Index</td>
<td>2.213</td>
<td>0.863</td>
<td>0.141</td>
<td>4.937</td>
</tr>
<tr>
<td>VIX Global volatility index</td>
<td>0.846</td>
<td>7.924</td>
<td>-10.278</td>
<td>38.010</td>
</tr>
<tr>
<td>Price of oil (log US$)</td>
<td>3.955</td>
<td>0.619</td>
<td>2.407</td>
<td>4.811</td>
</tr>
<tr>
<td>Price of agricultural raw materials (log US$)</td>
<td>4.708</td>
<td>0.162</td>
<td>4.437</td>
<td>5.104</td>
</tr>
<tr>
<td>Year-ahead growth forecast</td>
<td>0.028</td>
<td>0.025</td>
<td>-0.106</td>
<td>0.115</td>
</tr>
<tr>
<td>Year-ahead inflation forecast</td>
<td>0.040</td>
<td>0.069</td>
<td>-0.092</td>
<td>1.037</td>
</tr>
<tr>
<td>Inverse Chinn-Ito liberalization index</td>
<td>0.325</td>
<td>0.328</td>
<td>0.000</td>
<td>1.000</td>
</tr>
<tr>
<td>Schindler index of capital controls</td>
<td>0.382</td>
<td>0.333</td>
<td>0.000</td>
<td>1.000</td>
</tr>
<tr>
<td>Schindler index of inflows controls</td>
<td>0.356</td>
<td>0.315</td>
<td>0.000</td>
<td>1.000</td>
</tr>
<tr>
<td>Change in reserves (% of GPD)</td>
<td>0.694</td>
<td>3.523</td>
<td>-29.777</td>
<td>40.811</td>
</tr>
<tr>
<td>Observations</td>
<td></td>
<td></td>
<td></td>
<td>2233</td>
</tr>
</tbody>
</table>
Data: policy rates vs. shadow rates

(a) United States
(b) United Kingdom
(c) Eurozone

- Narrative policy rates (BIS)
- Shadow rates (Krippner, 2012)
- Use *shadow rates* if policy rate $\approx$ zero
This appendix presents tests for the stationarity properties of the monetary policy rate $R_t$. Figure F.10 plots the policy rate against its lagged level. As the figure illustrates, the policy rate exhibits substantial persistence and indicates the possibility of the existence of a unit root, with significant amount of data clustered around the 45-degree line. Formal country-specific and panel-based unit root tests are presented in Tables F.11 and F.12, respectively. As the country-specific tests indicate, we fail to reject the unit root null for well over half of the countries in the sample.

Panel tests, which provide additional power, yield similarly mixed results. While a majority of homogenous tests that impose a common autoregressive parameter on each panel are able to reject the null, they do so at only a 10 percent significance level. In contrast, a majority of heterogeneous tests allowing for panel-specific AR parameters fail to reject the null. It is worth highlighting that the one heterogeneous test that rejects the null hypothesis, Pesaran's Cross-sectionally Augmented Dickey-Fuller (CADF) test, is robust to cross-sectional dependence and therefore may have greater power in a setting where spatial dependence is important. Nevertheless, the alternative hypothesis in the CADF test is that a fraction of the panels are stationary, consistent with the mixed results provided by country-specific tests.

Finally, the Hadri Lagrange-multiplier test, in Table F.12, rejects the null hypothesis that all panels are stationary. This indicates that, consistent with the previous tests, a non-zero fraction of the panels are non-stationary. Together, the country-specific and panel-based unit root tests indicate that non-stationarity is likely a valid concern.

### Table F.12: Panel unit root tests

<table>
<thead>
<tr>
<th>Test</th>
<th>Statistic</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Homogenous tests</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Levin-Lin-Chu (adj $t$)</td>
<td>-1.486</td>
<td>(0.069)</td>
</tr>
<tr>
<td>Harris-Tzavalis ($Z$)</td>
<td>-1.388</td>
<td>(0.083)</td>
</tr>
<tr>
<td>Breitung ($\lambda$)</td>
<td>0.082</td>
<td>(0.533)</td>
</tr>
<tr>
<td><strong>Heterogeneous tests</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Im-Pesaran-Shin ($\bar{W}_t$)</td>
<td>-0.956</td>
<td>(0.169)</td>
</tr>
<tr>
<td>Fisher ($Z$)</td>
<td>-0.998</td>
<td>(0.159)</td>
</tr>
<tr>
<td>Pesaran CADF ($\bar{z}_t$)</td>
<td>-2.239</td>
<td>(0.013)</td>
</tr>
<tr>
<td><strong>Stationarity test</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hadri LM ($z$)</td>
<td>22.368</td>
<td>(0.000)</td>
</tr>
</tbody>
</table>

Note: Homogenous tests refer to panel tests with a common autoregressive coefficient. These test the null hypothesis that all panels contain a unit root. Heterogeneous tests refer to panel tests that assume panel-specific autoregressive coefficients. In these tests, the alternative hypothesis is that some of the panels are stationary. The Hadri LM stationarity test, in contrast, tests the null hypothesis that all panels are stationary against the alternative hypothesis that at least some panels contain unit roots.
Peak reactions

Figure 5: Peak partial equilibrium spillover effects

(a) USA → ROW

What is perhaps most remarkable is the strong implied peak spillovers from the Eurozone on the United States. While the point estimate for the peak effect of a shock in the Eurozone on the U.S. is well below unity, as panel (b) reports, we nevertheless cannot reject the full pass-through null at standard confidence levels.

Note:

\[ \text{Peak effect: } \quad dr_{\text{peak}} = \hat{\delta} W_\ell d u_\ell \]

Full passthrough?

\[ dr_{\text{peak}} = 1 \]
### Table 3: Robustness of strategic spillover estimates to common factors and alternative specifications

#### (a) Weighting Matrix ($W$): Gross bilateral bank positions

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Wr$</td>
<td>0.882***</td>
<td>0.767***</td>
<td>0.782***</td>
<td>0.781***</td>
<td>0.666***</td>
<td>0.733***</td>
</tr>
<tr>
<td></td>
<td>(0.236)</td>
<td>(0.195)</td>
<td>(0.242)</td>
<td>(0.244)</td>
<td>(0.143)</td>
<td>(0.201)</td>
</tr>
<tr>
<td>Observations</td>
<td>1008</td>
<td>966</td>
<td>1008</td>
<td>1008</td>
<td>1008</td>
<td>948</td>
</tr>
<tr>
<td>Anderson-Rubin test ($\chi^2$)</td>
<td>2.473</td>
<td>3.783</td>
<td>5.018</td>
<td>4.769</td>
<td>3.363</td>
<td>4.914</td>
</tr>
<tr>
<td>$p$-value</td>
<td>0.116</td>
<td>0.052</td>
<td>0.025</td>
<td>0.029</td>
<td>0.067</td>
<td>0.027</td>
</tr>
</tbody>
</table>

#### (b) Weighting Matrix ($W$): Gross bilateral investment position

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Wr$</td>
<td>0.896***</td>
<td>0.834***</td>
<td>0.694***</td>
<td>0.690***</td>
<td>0.725***</td>
<td>0.685***</td>
</tr>
<tr>
<td></td>
<td>(0.173)</td>
<td>(0.159)</td>
<td>(0.231)</td>
<td>(0.241)</td>
<td>(0.141)</td>
<td>(0.218)</td>
</tr>
<tr>
<td>Observations</td>
<td>1715</td>
<td>1647</td>
<td>1715</td>
<td>1715</td>
<td>1715</td>
<td>1537</td>
</tr>
<tr>
<td>Anderson-Rubin test ($\chi^2$)</td>
<td>3.786</td>
<td>5.056</td>
<td>4.433</td>
<td>3.947</td>
<td>3.488</td>
<td>3.983</td>
</tr>
<tr>
<td>$p$-value</td>
<td>0.052</td>
<td>0.025</td>
<td>0.035</td>
<td>0.047</td>
<td>0.062</td>
<td>0.046</td>
</tr>
</tbody>
</table>

- **Common factors?**
  - No
  - Yes

- **Common GFC effects?**
  - No
  - Yes

- **Country-specific GFC effects?**
  - No
  - Yes

- **Time FE?**
  - No
  - Yes

- **Additional covariates?**
  - No
  - Yes

- **Drop outliers?**
  - No
  - Yes

Note: This table reports Two-Step GMM estimates of the SAR model in (4). The dependent variable is the first difference of the monetary policy interest rate. The vector of exogenous observables $X_t$ includes lags of quarterly real GDP growth, the change in inflation, as well as country-specific forecasts of growth and inflation. Common factors refers to the inclusion of the VIX index and indices for the global price of oil and commodities. Additional covariates refers to the inclusion of lagged unemployment and changes in the real exchange rate. Driscoll-Kraay standard-errors are reported in parenthesis.

*p< 0.01, *p< 0.05, *p< 0.1.*

Defining $W_{\`}$ as the vector given by the $\`$-th column of $W$, the partial equilibrium strategic spillovers arising from a shock in country $\`$ is given by:

$$dr_{\`}^{PE} = \hat{W}_{\`} d_u$$

(9)

where each element of $dr_{\`}^{PE}$ measures the direct reaction in a given country to a shock in country $\`$. Clearly, if a country is not linked to country $\`$ the direct spillover effect will be zero. Similarly, we can use the model's reduced form (6) to express the general equilibrium spillover as:

$$dr_{\`}^{GE} = B_{\`} d_u$$

(10)

where $B_{\`}$ is the $\`$-th column of $B = (I \hat{W})^{-1}$. Each element of $dr_{\`}^{GE}$ contains both the direct effects of a shock in country $\`$ and the additional spillovers due to the endogenous responses of every other country in the network.
This appendix reports results for overidentified models using multiple instruments in the first-stage. Specifically, every model in Table A.7 instruments \( Wr \) using second-order and third-order spatial lags of real growth and inflation forecast errors. The overidentified estimates of \( \hat{\theta} \) are qualitatively similar to those reported above, albeit somewhat smaller. This is likely due to a weak instruments problem, as the overidentified models exhibit substantially smaller first-stage F-statistics.

### Table A.7: Estimates of strategic spillovers \( \hat{\theta} \) with overidentified models

(a) **Weighting Matrix \((W)\):** Gross bilateral bank positions

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( Wr )</td>
<td>0.804***</td>
<td>0.731***</td>
<td>0.731***</td>
<td>0.693***</td>
<td>0.637***</td>
<td>0.638***</td>
</tr>
<tr>
<td></td>
<td>(0.133)</td>
<td>(0.141)</td>
<td>(0.194)</td>
<td>(0.191)</td>
<td>(0.117)</td>
<td>(0.162)</td>
</tr>
<tr>
<td>Observations</td>
<td>1008</td>
<td>966</td>
<td>1008</td>
<td>1008</td>
<td>1008</td>
<td>950</td>
</tr>
<tr>
<td>Kleibergen-Paap F-stat</td>
<td>2.400</td>
<td>1.978</td>
<td>3.408</td>
<td>3.378</td>
<td>5.114</td>
<td>6.937</td>
</tr>
<tr>
<td>Overidentification test</td>
<td>0.182</td>
<td>0.673</td>
<td>0.129</td>
<td>0.347</td>
<td>0.240</td>
<td>0.517</td>
</tr>
<tr>
<td>Anderson-Rubin test ( (\chi^2) )</td>
<td>3.476</td>
<td>4.609</td>
<td>5.633</td>
<td>5.518</td>
<td>3.971</td>
<td>5.189</td>
</tr>
<tr>
<td>( p-value )</td>
<td>0.482</td>
<td>0.330</td>
<td>0.228</td>
<td>0.238</td>
<td>0.410</td>
<td>0.268</td>
</tr>
</tbody>
</table>

(b) **Weighting Matrix \((W)\):** Gross bilateral investment

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( Wr )</td>
<td>0.838***</td>
<td>0.814***</td>
<td>0.720***</td>
<td>0.628***</td>
<td>0.672***</td>
<td>0.632***</td>
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<tr>
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<td>(0.117)</td>
<td>(0.114)</td>
<td>(0.216)</td>
<td>(0.182)</td>
<td>(0.123)</td>
<td>(0.174)</td>
</tr>
<tr>
<td>Observations</td>
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<td>1647</td>
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<td>1715</td>
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<td>1540</td>
</tr>
<tr>
<td>Kleibergen-Paap F-stat</td>
<td>2.962</td>
<td>2.631</td>
<td>3.894</td>
<td>4.269</td>
<td>4.227</td>
<td>5.144</td>
</tr>
<tr>
<td>Overidentification test</td>
<td>1.631</td>
<td>1.451</td>
<td>1.704</td>
<td>2.125</td>
<td>2.361</td>
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<td>Anderson-Rubin test ( (\chi^2) )</td>
<td>5.420</td>
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<td>0.191</td>
<td>0.282</td>
<td>0.211</td>
<td>0.234</td>
</tr>
</tbody>
</table>

- Common factors? No Yes No No No No
- Common GFC effects? No No Yes No No No
- Country-specific GFC effects? No No No Yes No No
- Time FE? No No No No Yes Yes
- Additional covariates? No No No No No Yes
- Drop outliers? No No No No No Yes

Note: This table reports Two-Step GMM estimates of the SAR model in (4). The dependent variable is the first difference of the monetary policy interest rate. The vector of exogenous observables \( X_t \) includes lags of quarterly real GDP growth, the change in inflation, as well as country-specific forecasts of growth and inflation. Common factors refers to the inclusion of the VIX index and indices for the global price of oil and commodities. Additional covariates refers to the inclusion of lagged unemployment and changes in the real exchange rate. Driscoll-Kraay standard-errors are reported in parenthesis. \( \ast \ast \ast p< 0.01, \ast \ast p< 0.05, \ast p< 0.1. \)
### (a) Weighting Matrix (W): Gross bilateral bank positions

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( Wr )</td>
<td>0.882***</td>
<td>0.767***</td>
<td>0.782***</td>
<td>0.781***</td>
<td>0.666***</td>
<td>0.733***</td>
</tr>
<tr>
<td></td>
<td>(0.236)</td>
<td>(0.195)</td>
<td>(0.242)</td>
<td>(0.244)</td>
<td>(0.143)</td>
<td>(0.201)</td>
</tr>
<tr>
<td>Observations</td>
<td>1008</td>
<td>966</td>
<td>1008</td>
<td>1008</td>
<td>1008</td>
<td>948</td>
</tr>
<tr>
<td>Anderson-Rubin test (( \chi^2 ))</td>
<td>2.473</td>
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<td>5.018</td>
<td>4.769</td>
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<td>4.914</td>
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<tr>
<td>p-value</td>
<td>0.116</td>
<td>0.052</td>
<td>0.025</td>
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<td>0.027</td>
</tr>
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<td>No</td>
<td>No</td>
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<tr>
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<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
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<tr>
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<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Time FE?</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Additional covariates?</td>
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<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Drop outliers?</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Note: This table reports CUE estimates of the SAR model in (4). The dependent variable is the first difference of the monetary policy interest rate. The vector of exogenous observables \( X_t \) includes lags of quarterly real GDP growth, the change in inflation, as well as country-specific forecasts of growth and inflation. Common factors refers to the inclusion of the VIX index and indices for the global price of oil and commodities. Additional covariates refers to the inclusion of lagged unemployment and changes in the real exchange rate. Driscoll-Kraay standard-errors are reported in parenthesis. \( ^{*} \) \( p<0.01 \), \( ^{*} \) \( p<0.05 \), \( ^{*} \) \( p<0.1 \).
## Alternative network structures $W$

### Table D.10: Estimates of strategic spillover with alternative weighting matrices

(a) **Weighting Matrix (W):** Gross bilateral trade

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$W_{rt}$</td>
<td>1.078***</td>
<td>0.980***</td>
<td>1.046***</td>
<td>1.034***</td>
<td>0.881***</td>
<td>0.898***</td>
</tr>
<tr>
<td></td>
<td>(0.201)</td>
<td>(0.186)</td>
<td>(0.270)</td>
<td>(0.264)</td>
<td>(0.136)</td>
<td>(0.207)</td>
</tr>
<tr>
<td>Observations</td>
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<td>1693</td>
<td>1757</td>
<td>1757</td>
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<td>1589</td>
</tr>
<tr>
<td>Anderson-Rubin test ($\chi^2$)</td>
<td>3.819</td>
<td>5.810</td>
<td>8.585</td>
<td>8.214</td>
<td>4.279</td>
<td>4.342</td>
</tr>
<tr>
<td>p-value</td>
<td>0.051</td>
<td>0.016</td>
<td>0.003</td>
<td>0.004</td>
<td>0.039</td>
<td>0.037</td>
</tr>
</tbody>
</table>

(b) **Weighting Matrix (W):** Relative output size

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$W_{rt}$</td>
<td>1.144***</td>
<td>1.070***</td>
<td>1.116***</td>
<td>1.092***</td>
<td>0.893***</td>
<td>0.664***</td>
</tr>
<tr>
<td></td>
<td>(0.216)</td>
<td>(0.202)</td>
<td>(0.357)</td>
<td>(0.351)</td>
<td>(0.161)</td>
<td>(0.237)</td>
</tr>
<tr>
<td>Observations</td>
<td>1757</td>
<td>1693</td>
<td>1757</td>
<td>1757</td>
<td>1757</td>
<td>1568</td>
</tr>
<tr>
<td>Anderson-Rubin test ($\chi^2$)</td>
<td>3.691</td>
<td>5.069</td>
<td>5.489</td>
<td>4.973</td>
<td>3.912</td>
<td>3.765</td>
</tr>
<tr>
<td>p-value</td>
<td>0.055</td>
<td>0.024</td>
<td>0.019</td>
<td>0.026</td>
<td>0.048</td>
<td>0.052</td>
</tr>
</tbody>
</table>

- **Common factors?**
  - No
  - Yes
- **Common GFC effects?**
  - No
  - No
  - Yes
- **Country-specific GFC effects?**
  - No
  - No
  - Yes
- **Time FE?**
  - No
  - No
  - No
  - Yes
  - Yes
- **Additional covariates?**
  - No
  - No
  - No
  - Yes
  - Yes
- **Drop outliers?**
  - No
  - No
  - No
  - No
  - Yes

Note: This table reports Two-Step GMM estimates of the SAR model in (4). The dependent variable is the first difference of the monetary policy interest rate. The vector of exogenous observables $X_t$ includes lags of quarterly real GDP growth, the change in inflation, as well as country-specific forecasts of growth and inflation. Common factors refers to the inclusion of the VIX index and indices for the global price of oil and commodities. Additional covariates refers to the inclusion of lagged unemployment and changes in the real exchange rate. Driscoll-Kraay standard-errors are reported in parenthesis. $\ast\ast\ast p< 0.01, \ast\ast p< 0.05, \ast p< 0.1. $
Heterogeneous local projections

Table 6: Dynamic effect of capital controls

<table>
<thead>
<tr>
<th>Horizon</th>
<th>( \hat{W}r )</th>
<th>SE</th>
<th>( \hat{W}r \cdot K_{SCH} )</th>
<th>SE</th>
<th>( K_{SCH} )</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>( h = 0 )</td>
<td>0.760***</td>
<td>(0.124)</td>
<td>-0.576**</td>
<td>(0.228)</td>
<td>-0.001</td>
<td>(0.001)</td>
</tr>
<tr>
<td>( h = 1 )</td>
<td>1.667***</td>
<td>(0.332)</td>
<td>-0.920***</td>
<td>(0.319)</td>
<td>-0.001</td>
<td>(0.001)</td>
</tr>
<tr>
<td>( h = 2 )</td>
<td>1.757***</td>
<td>(0.463)</td>
<td>-1.011**</td>
<td>(0.431)</td>
<td>-0.001</td>
<td>(0.002)</td>
</tr>
<tr>
<td>( h = 3 )</td>
<td>1.645***</td>
<td>(0.427)</td>
<td>-1.004***</td>
<td>(0.370)</td>
<td>-0.001</td>
<td>(0.002)</td>
</tr>
<tr>
<td>( h = 4 )</td>
<td>1.335***</td>
<td>(0.475)</td>
<td>-1.197***</td>
<td>(0.427)</td>
<td>-0.001</td>
<td>(0.003)</td>
</tr>
<tr>
<td>( h = 5 )</td>
<td>0.840*</td>
<td>(0.495)</td>
<td>-1.167**</td>
<td>(0.481)</td>
<td>-0.001</td>
<td>(0.003)</td>
</tr>
<tr>
<td>( h = 6 )</td>
<td>0.393</td>
<td>(0.509)</td>
<td>-1.088</td>
<td>(0.707)</td>
<td>-0.001</td>
<td>(0.003)</td>
</tr>
<tr>
<td>( h = 7 )</td>
<td>0.107</td>
<td>(0.617)</td>
<td>-1.018</td>
<td>(0.803)</td>
<td>-0.002</td>
<td>(0.003)</td>
</tr>
<tr>
<td>( h = 8 )</td>
<td>0.067</td>
<td>(0.655)</td>
<td>-0.799</td>
<td>(0.845)</td>
<td>-0.002</td>
<td>(0.003)</td>
</tr>
</tbody>
</table>

\[
R_h - R_{t-1} = (\delta_h + \theta_h K_t) \cdot W_r + \eta_h K_t + \beta_h X_t + u_t
\]
Partial and General Equilibrium Effects

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### Weighting matrix ($W$):
Gross bilateral investment position