Determining Exchange Rate Pass-through in Russia

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Overview

- Price stability in an open economy depends on import prices $\Rightarrow$ local price level is subject to exchange rate fluctuations;
- In general, there is no one-to-one correspondence: producers along the distribution chain may adjust their markup to mitigate exchange rate shock;
- Russia has been exposed to numerous different macroeconomic shocks, especially oil price fluctuations $\Rightarrow$ it is crucial to estimate shock-dependent exchange rate pass-through.

- Only one work (Khotulev, 2020) estimates shock-dependent ERPT using DSGE;
- Values vary from paper to paper as well as data time-frame.

Paper	Currency	Data	Infl. aggr.	Length	ERPT
Oomes et al., 2005	NEER	1996–2004	CPI	Short-run	0.4–0.5
Korhonen et al., 2006	USD	1999–2004	ULC[1]	Long-run	-0.42
Dobrynskaya et al., 2008	NEER	1995–2002	CPI	Long-run	0.35
Kataranova, 2010	USD	2000–2008	CPI	Short-run	0.06–0.2
Beckmann et al., 2013	USD	1999–2010	CPI	Long-run	-0.17
Ponomarev et al., 2016	NEER	2000–2012	CPI	Short-run	0.046
Faryna, 2016	USD	2000–2015	CPI Core	Long-run	0.1
Sinyakov et al., 2019	NEER	(2016–2017)	CPI	Long-run	0.35
Khotulev, 2020	NEER	2005–2019	CPI	Long-run	0.16

[1] Unit labour cost.

- Basic method — estimation of ARDL model:

$$INFL_t = \alpha_0 + \alpha_1 NEER_t + \alpha_2 NEER_{t-1} + \ldots + \beta' \gamma_t + \epsilon_t \qquad (1)$$

- Then, unconditional exchange rate pass-through (**ERPT**) value for horizon *t* is as follows:

$$ERPT_h = \sum_{i=1}^{h} \alpha_i \qquad (2)$$

- Main drawback — ERPT value is unconditional, shock-independent — not informative.

- Another option is to estimate VAR (either using frequentist or Bayesian approach) and calculate price-to-exchange rate ratio (PERR, as in Ortega et al. (2020)), for example:

$$Y_t = \mathbf{C} + \mathbf{B_1} Y_{t-1} + \ldots + u_t, \quad \mathbb{E}(uu') = \Sigma_u \tag{3}$$

$$Y_t = \left[\text{CPI}_t, \text{GDP}_t, \text{IR}_t, \text{ER}_t, \text{OIL}_t\right]', \; u_t = \left[u_t^{\text{CPI}}, \ldots, u_t^{\text{OIL}}\right]'. \tag{4}$$

$$PERR_{h,shock} = \frac{\sum_{t=1}^{h} \text{IRF}_{t,shock}^{\text{CPI}}}{\sum_{t=1}^{h} \text{IRF}_{t,shock}^{\text{ER}}}, \tag{5}$$

- Reduced-form VAR does not capture structural shocks (Σ_u is not diagonal) $\Rightarrow$ need to use identification scheme.

ER = exchange rate, IR = interest rate, IRF = impulse response function.

- Full-form VAR:

$$\mathbf{A_0} Y_t = \tilde{\mathbf{C}} + \mathbf{A_1} Y_{t-1} + \ldots + \epsilon_t, \quad \mathbb{E}(\epsilon\epsilon') = \Sigma_\epsilon = \mathbb{I}_n. \tag{6}$$

$\epsilon_t = \left[\epsilon_t^{\text{CPI}}, \ldots, \epsilon_t^{\text{OIL}}\right]'$ is a vector of *structural* shocks at *t*, and model captures contemporaneous relations of variables.

- The most common way to get matrix of structural parameters — A_0 — is to use Cholesky decomposition of covariance matrix Σ_u:

$$\Sigma_u = (A_0)^{-1} \Sigma_\epsilon (A_0)^{-1'} = (A_0)^{-1} (A_0)^{-1'}. \tag{7}$$

- A huge drawback — this identification scheme is recursive (upper-/lower-triangular) $\Rightarrow$ rigid.

- (Arias et al., 2014) proposes to use agnostic suggestions about signs and zero values of IRF to identify shocks:
    1. Obtain n draws from posterior distribution of BVAR;
    2. For each draw generate m random matrices X_n and use QR decomposition to get orthonormal matrices Q such that $Q'Q = I_n$. Transform Q using an algorithm described in paper, if there are zero restrictions;
    3. For each matrix Q calculate $IRF_h \times Q$, where IRF_h is column-stacked IRF values calculated from corresponding draw, and check whether the result satisfies zero and sign restrictions.
- Suitable for under-identified and just-identified models;
- There should be less zero restrictions than an order of a particular shock.

Data
Variables

- Quarterly data, 2005Q2–2020Q4, 63 observations;
- All variables, except for interest rate, are in growth rates;
- Two CPI aggregates: full and core (excl. fuel, fruits and vegetables, community transport services, utilities etc.).

Variable	Description	Source
Oil price	Brent oil price nominated in US dollars, quarterly average, QoQ.	Bloomberg
Interest rate	MIACR 31–180 days, quarterly average.	CBR
Exchange rate	Nominal effective exchange rate (NEER) of ruble, Ruble appreciation = NEER decline, QoQ, Central Bank of Russia methodology.	CBR
Output	Russian real GDP (2015Q1 = 100), seasonally adjusted by institution, QoQ.	FRED
Price level	Consumer price index and core consumer price index, QoQ, seasonally adjusted (X13-SEATS), Rosstat methodology.	Rosstat

- Two 1-lag BVAR specifications: full and core CPI for price level variable. Order is chosen based on SIC criterion. Conjugate normal inverse-Wishart prior is used;
- 500 draws from posterior distribution, 1000 random *Q* matrices for each draw;
- Restriction scheme is based on (Forbes et al., 2018) and (Sinyakov et al., 2019);
- Sign restrictions are for contemporaneous and next quarter reaction, zero restrictions are only contemporaneous.

Variable	Demand shock	Supply shock	Monetary shock	Exchange rate shock	Global persistent shock
CPI/Core	+	−	−	+	?
Real GDP	+	+	−	?	?
Interest rate	+	?	+	+	?
NEER	?	?	−	+	−
Oil price	0	0	0	0	+

- Almost all PERR values for core composition are higher;
- Exchange rate shock pass-through is the highest in LR for both specifications;
- Global shock PERR is low for full CPI and huge for core composition;
- Supply shock PERRs are comparable for both specifications;
- Except for supply shock, pass-through is faster for core CPI.

Horizion	Short-run (1Q)		Long-run (4Q)	
Shock	PERR (CPI)	PERR (Core)	PERR (CPI)	PERR (Core)
Global persistent shock	0.070	0.344	0.158	0.427
Monetary shock	0.044	0.110	0.281	0.448
Exchange rate shock	0.146	0.197	0.403	0.565
Supply shock	-0.239	-0.124	-0.356	-0.391
Demand shock	-0.037	-0.295	-0.133	-0.354

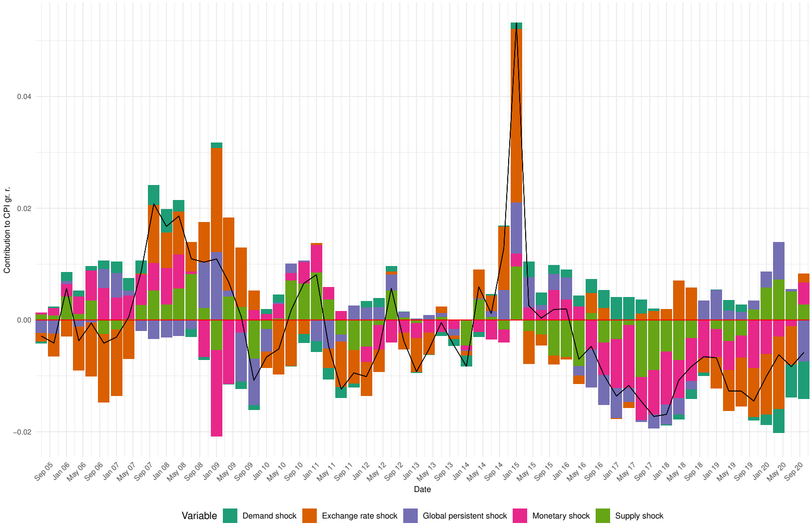

Figure: Hist. decomp. of demeaned CPI gr. r. time series.

Conclusion

- Result is comparable to (Khotulev, 2020) for monetary and global shocks;
- PERR values are higher for Russia comparing to Euro area;
- Exchange rate pass-through is higher and faster to core CPI;
- COVID-19 crisis has been driven mainly by global persistent and demand shocks;
- Policy implications:
  1. Pass-through during exogenous ER shock is high, more aggressive exchange rate management may be beneficial;
  2. Monetary policy vs. domestic supply trade-off: positive monetary shock cools down both prices and output in SR, but may be a source of negative supply shocks in LR.

Q&A

1. Introduction
2. Literature Review
3. Methods
4. Data and model
5. Results
6. Conclusion

- Software discussion
- How is Q matrix constructed with zero restrictions?
- Bayesian model specification
- Data plot, Interest rate vs. inflation plot
- Full CPI IRFs, Core CPI IRFs
- Core CPI HD

1. Matlab — `ZeroSignVAR`:
   - No long-run IRFs;
   - Bug with hist. dec. figures — some colors are erroneously identical.
2. R — `BVAR`:
   - No long-run IRFs;
   - Only contemporaneous restrictions;
   - No historical decomposition.
3. Eviews — `arw`:
   - No long-run IRFs;
   - Rigid restrictions.
4. R — `ZerosignR` — my implementation, which implements long-run IRF restrictions. *Under development*.

Return to Q&A

Annex

Zero restrictions on Q matrix

Data: Z = zero restrictions matrix, n = number of zero restrictions, Z_j = j-th shock zero restrictions, $1 \leq j \leq n$, z_j = number of zero restrictions for shock j such that $z_j \leq n - j$.

$R_j(A_0, A_+) = \begin{bmatrix} Z_j \times IRF(A_0, A_+) \\ Q'_{j-1} \end{bmatrix}$. $Q_j = [q_1, \ldots, q_j]'$, q_j = j-th column of Q, $Q_0 = q_0 \equiv \emptyset$.

```
for j = 1 ... n do
    N_{j-1} = Null(R_j);
    x_j ~ N_n(0, 1);
    q_j = N_{j-1} (N'_{j-1} x_j) / ||N'_{j-1}||;
end
```

$$
\begin{aligned}
&\textbf{for } j = 1 \ldots n \textbf{ do} \\
&\quad N_{j-1} = \text{Null}(R_j); \\
&\quad x_j \sim \mathbb{N}_n(0, 1); \\
&\quad q_j = N_{j-1} \frac{N'_{j-1} x_j}{\|N'_{j-1}\|}; \\
&\textbf{end}
\end{aligned}
$$

- Zero restrictions are held by construction.

◂ Return to Q&A

- Conjugate normal-inverse Wishart distribution for BVAR (underline for prior values):

$$\begin{cases} \Sigma \sim \mathcal{IW}(\underline{S}, \underline{\nu}) \\ \mathbf{B}|\Sigma \sim \mathcal{N}(\underline{\mathbf{B}}, \Sigma \otimes (X'X)) \end{cases} \tag{8}$$

  - Σ = error covariance matrix, $\mathcal{IW}$ = inverse-Wishart distribution, S = scale matrix (pos. def.) of $\mathcal{IW}$, ν = degrees of freedom;
  - $\mathbf{B}$ = matrix of coefficients, $\mathcal{N}$ = normal multivariate distribution, X = matrix of regressors (columns of lagged Y), $\otimes$ = Kronecker product;
  - No need for Gibbs sampler and burn-in — parameters are derived analytically;
  - Can use initial Σ from OLS.

Return to Q&A

1. *Why didn't I estimate unconditional ERPT?*
    - Shock-dependent ERPT (PERR) is not studied well for Russia;
    - Unconditional ERPT requires discussion about specification of model and choice of data — a whole separate dissertation would have been written;
2. *Why didn't I split time series to periods before/after adoption of floating regime?*
    - 24 quarterly observations after Bank of Russia's decision to adopt floating regime — few for estimation of VAR, even using Bayesian approach.
3. *Why don't I capture adoption effect using a separate shock?*
    - Quite unclear how to do that in SVAR framework;
    - Shock vs. structure problem: can be addressed by estimating threshold VAR or TVP-VAR, but identification is cumbersome, and there are no works solving this issue.

◂ Return to Q&A ▸ ERPT estimation

- À-la (Campa et al., 2005) — ARDL model with NEER as exchange rate, GDP and oil as proxies:

$$CPI_t = c + \sum_{i=0}^{4} \alpha_i NEER_{t-i} + \sum_{i=0}^{2} \beta_i GDP_{t-i} + \sum_{i=0}^{2} \gamma_i OIL_{t-i} + \varepsilon_t. \quad (9)$$

- Short-run (2Q) ERPT: $\sum_{i=0}^{1} \beta_i = 0.199$ (p<0.0001);
- Long-run (4Q) ERPT: $\sum_{i=0}^{3} \beta_i = 0.272$ (p<0.0001);
- Roughly speaking, LR ERPT is half as much as LR PERR for any shock.

Return to Q&A

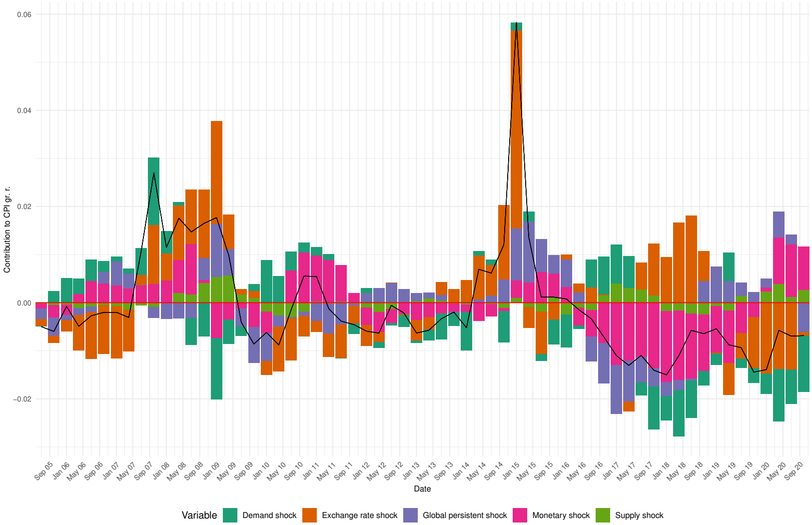

Figure: Hist. decomp. of demeaned NEER gr. r. time series, core CPI.

Return to Q&A

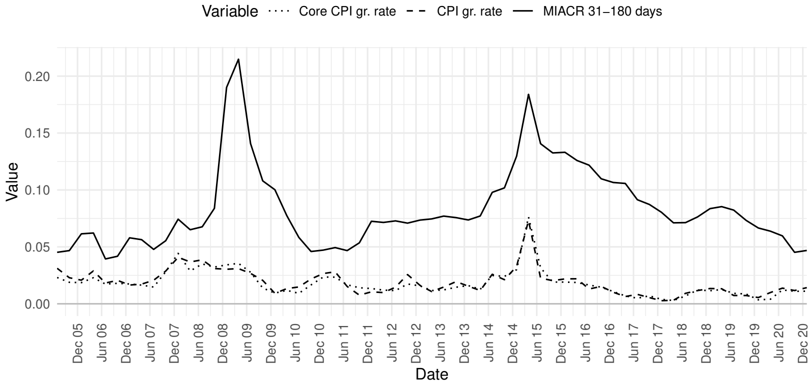

Figure: Time series of interest rate and growth rates of full and core CPI compositions.

Return to Q&A

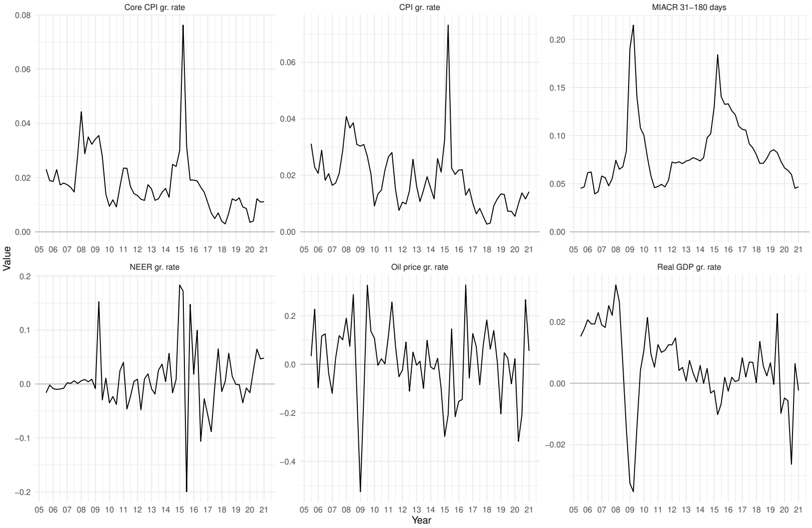

Figure: Time series of variables used, growth rates except for interest rate.

Return to Q&A

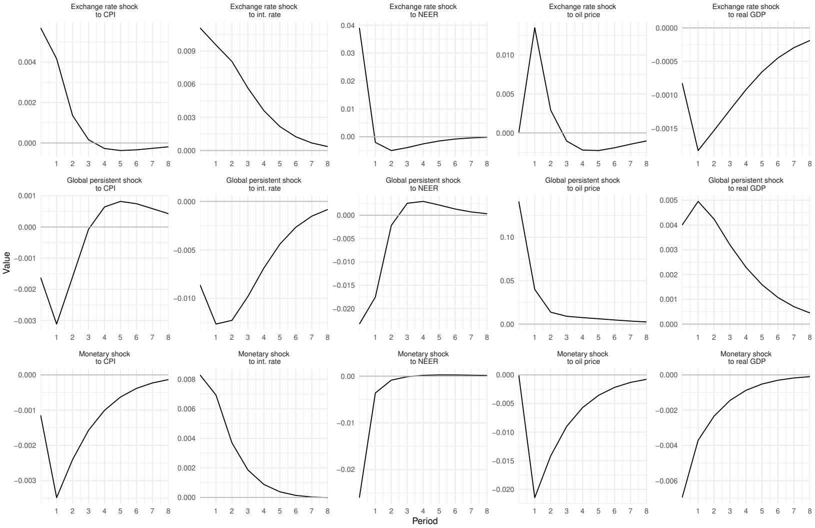

Figure: Impulse response functions of full model, CTM (1).

Return to Q&A
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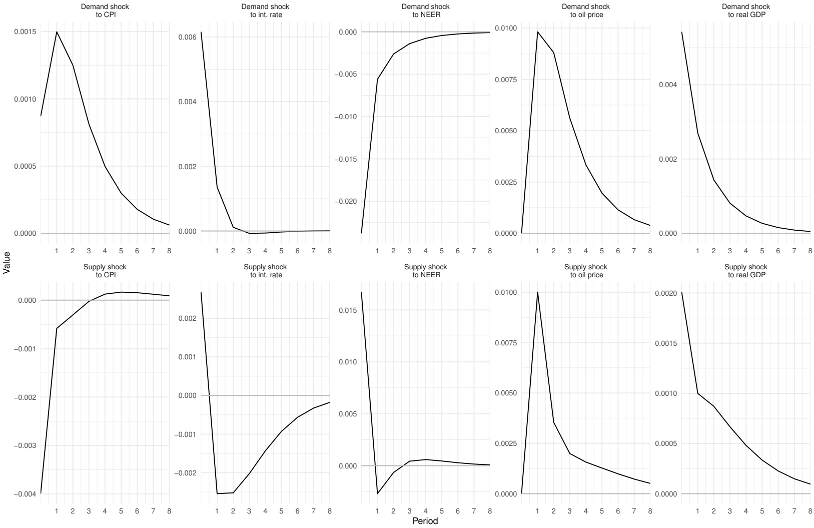

Figure: Impulse response functions of full model, CTM (2).

Return to Q&A

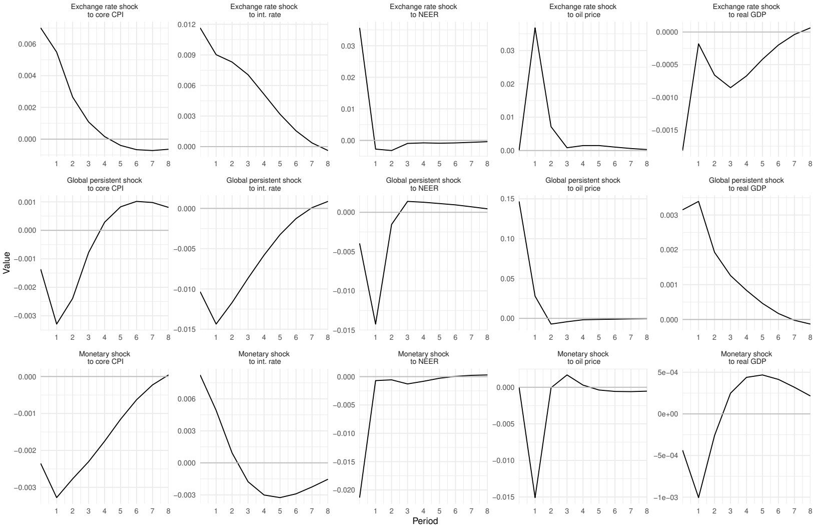

Figure: Impulse response functions of core model, CTM (1).

Return to Q&A
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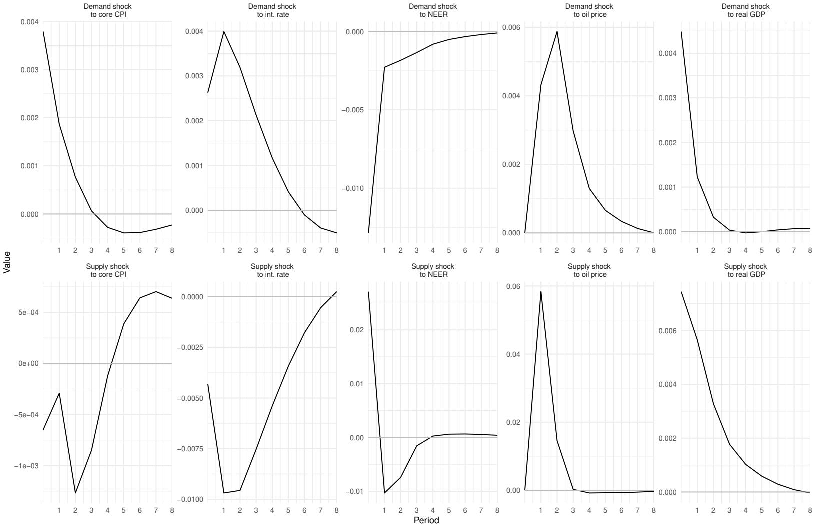

Figure: Impulse response functions of core model, CTM (2).

Return to Q&A

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