Global commodity price uncertainty

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Background and Motivation

- World Energy Council (2017): "Commodity price uncertainty is the global number one insomnia issue affecting energy leaders' decision making."
- For commodity exporters, changes in global commodity price uncertainty could be important in addition to changes in price level
- This paper extends the literature by investigating how **global commodity price uncertainty** affects commodity exporter's real economic activity.

Background and Motivation (cont)

- Existing studies focus on measuring and quantifying the impact of aggregate macreconomics uncertainty (Bloom, 2009; Jurado et. al., 2015); terms-of-trade uncertainty (Pfeifer et. al, 2012); commodity price fluctuations (Charnavoki & Dolado, 2014; Kilian, 2009; Kulish & Rees, 2017)

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- Less on commodity price uncertainty. Even so, most focus on oil price uncertainty (Baskaya et. al., 2013; Carapole et. al., 2015; Diaz et. al., 2016; Luo & Qin, 2016)
- Commodity price uncertainty proxies:
  - Volatility: CBOE crude oil volatility index (OVX), realised variance (Luo & Qin, 2016)
  - Model-based estimates: GARCH (Carapole et. al., 2015; Dehn, 2000; Diaz et. al., 2016); VAR with SV in mean (Jo, 2014)

This paper

- 1/ Construct global commodity price uncertainty proxies as the time-varying conditional volatility of the one-period ahead forecast error
    - measures how unpredictable are current commodity prices relative to their past prices
    - capture broad commodity uncertainty (47 global price series) - free from uncertainty of individual commodity series

This paper (cont)

- 2/ Empirical VAR evidence
- 3/ Interpreting the impact of uncertainty in a SOE DSGE model
    - SOE with commodity tradable sector (Rees et. al., 2016, Kulish & Rees, 2017)
    - Commodity price is subject to both level and volatility shock (Fernandez-Villaverde et. al., 2011; Pfeifer et. al., 2012; Baskaya et. al., 2013)
    - Calibrate using VAR-DSGE impulse response function matching *(in progress)*

Literature Review

- **Uncertainty:** Bachmann et al. (2013), Baker et al. (2016), Basu & Bundick (2017), Bloom (2009), Castelnuovo & Tran (2017), Fernandez-Villaverde et. al. (2011, 2015), Jurado et al. (2015), Istrefi & Mouabbi (2017), Scotti (2016), Rossi & Sekhposyan (2015), Tran (2017), Mumtaz & Theodoridis (2017)

  Commodity price uncertainty: Baskaya et. al. (2013), Carapole et. al. (2015); Dehn (2000), Jo (2014)
- **Commodity price**: Charnavoki & Dolado (2014); Deaton and Laroque (1992); Diaz et. a.l. (2016); Joets et. al. (2017); Kilian (2009)
- **Small open economies**: Gali & Monacelli (2005), Justiniano & Preston (2010), Kulish & Rees (2017), Lubik & Schorfheide (2007), Pfeifer et. al. (2012), Rees et. al. (2016)

Key results

- Clear peak during the global financial crisis and more volatile afterwards
- Commodity price uncertainty shock has significant impact on real economic activity in Canada, New Zealand and Norway but only modest in Australia
- DSGE model shows standard contractionary responses of key real economic activity variables to uncertainty shock

Global commodity price uncertainty index construction

- Jurado et. al. (2015): "What matters for economic decision making is not whether particular economic indicators have become more or less **variable**, but rather whether the economy has become more or less **predictable**"
- h-period ahead uncertainty, $\mathbf{U_{jt}(h)}$, of commodity price series, $\mathbf{y_{jt}} \in Y_t = (y_{1t}, \ldots, y_{Nt})$, is the conditional volatility of the un-forecastable component

$$U_{jt}(h) = \sqrt{E\left[(y_{jt+h} - E[y_{jt+h}|I_t])^2 | I_t\right]} \tag{1}$$

- Global commodity price uncertainty is the average of individual commodity price series:

$$U_t(h) = \sum_{j=1}^{N} \frac{1}{N} U_{jt}(h) \tag{2}$$

Econometrics model

- Proper measurement of uncertainty requires removing forecastable component $E[y_{j,t+h}|I_t]$
- For each commodity price series, $y_{jt}, j = 1, \ldots, N,$:

$$y_{j,t+1} = E[y_{jt+1}|I_t] + \upsilon_{j,t+1}$$

$$\upsilon_{j,t+1} = \sigma_{j,t+1}\epsilon_{j,t+1}$$

$$\log[(\sigma_{j,t+1})]^2 = \alpha_j + \beta_j \log[(\sigma_{jt})^2] + \tau_j\eta_{j,t+1}$$

where $\epsilon_{j,t+1}$ and $\eta_{j,t+1}$ are *iid* $N(0,1)$ $r.v$

- Require 2 ingredients:
  1. $\hat{E}[y_{jt+1}|I_t]$
  2. $\log[(\hat{\sigma}_{j,t})^2]$

Predictive model

- With additional predictors, X_{jt}

$$y_{jt+1} = \phi_{jt} y_{jt} + \rho_{jt} X_{jt} + \upsilon_{j,t+1}$$

- Then

$$\hat{E}[y_{jt+1}|I_t] = \phi_{jt} y_{jt} + \rho_{jt} X_{jt},$$

$$\hat{\upsilon}_{j,t+1} = y_{jt+1} - \hat{E}[y_{jt+1}|I_t]$$

- Important feature: one-step ahead prediction error of y_{jt+1} and predictors, X_{jt+1} have time-varying volatility to generate time-varying uncertainty in series y_{jt}.

Stochastic volatility estimate

- From the model: $\upsilon_{j,t+1} = \sigma_{j,t+1}\epsilon_{j,t+1}$. Take logs:

$$log[(\upsilon_{j,t+1})^2] = log[(\sigma_{j,t+1})^2] + log[(\epsilon_{j,t+1})^2]$$

$$log(\sigma_{j,t+1})^2 = \alpha_j + \beta_j log(\sigma_{jt})^2 + \tau_j \eta_{j,t+1}$$

- Bayesian estimation of SV models via MCMC methods using *stochvol* package in R (Kastner, 2016) suggested by Jurado et. al. (2015)

Computing Uncertainty

- For h=1

$$U_{jt}(1) = exp\{\alpha_j + \beta_j log(\sigma_{jt})^2 + \frac{1}{2}\tau_j^2\}$$

- For $h \geq 1$; let $q = \max(lags_y, lags_X, h)$; define $\mathcal{Y}_{it} \equiv (y_{jt}, \ldots, y_{j,t-q+1})$ and $\mathcal{X}_{jt} \equiv (X_{jt}, \ldots, X_{j,t-q+1})$

$$\begin{pmatrix} \mathcal{X}_{jt} \\ \mathcal{Y}_{jt} \end{pmatrix} = \begin{pmatrix} \Phi_j^{\mathcal{X}} & 0 \\ \Lambda_j & \Phi_j^{\mathcal{Y}} \end{pmatrix} \begin{pmatrix} \mathcal{X}_{j,t-1} \\ \mathcal{Y}_{j,t-1} \end{pmatrix} + \begin{pmatrix} \mathcal{V}_{jt}^{\mathcal{X}} \\ \mathcal{V}_{jt}^{\mathcal{Y}} \end{pmatrix}$$

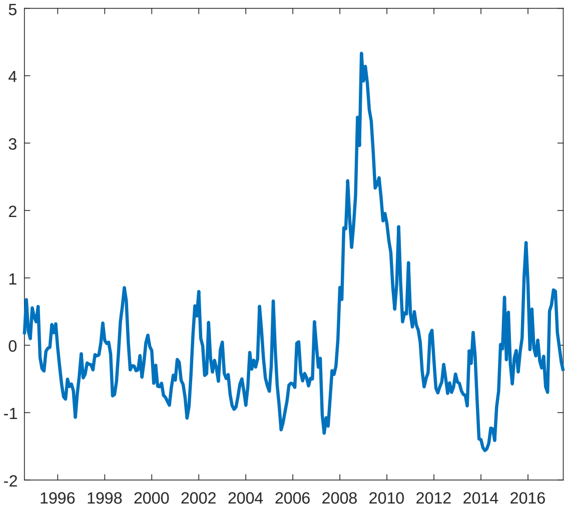
$$\Upsilon_{jt} = \Phi_j^{\Upsilon} \Upsilon_{j,t-1} + \mathcal{V}_{jt}^{\Upsilon}$$

Uncertainty in commodity price series, y_{it} is

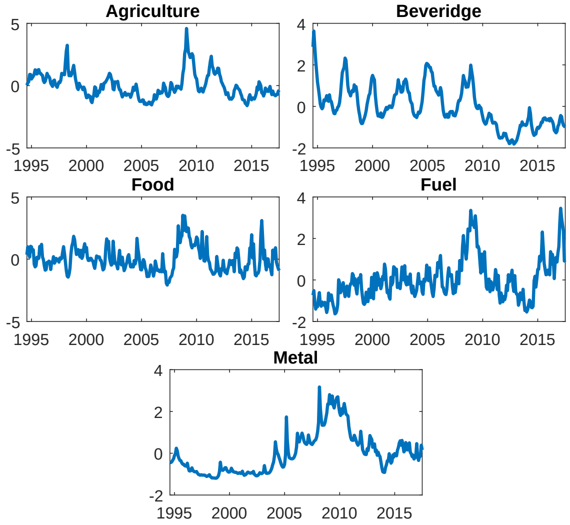
$$U_{jt}(h) = 1_j' U_{jt}^{\Upsilon}(h) 1_j = \Phi_j^{\Upsilon} U_{jt}^{\Upsilon}(h-1) \Phi_j^{\Upsilon'} + E_t \left[V_{j,t+h}^{\Upsilon} V_{j,t+h}^{\Upsilon} \right]$$

where 1_j is a selection vector and recursion holds $U_{jt}^{\Upsilon}(h=0)$

Global commodity price uncertainty index



Global commodity price uncertainty index by Group



Data and empirical implementation

- y_{jt}: 47 monthly standardised global individual commodity price series, 1994:01-2017:05 (IMF)
- Five groups: Food, Beveridge, Raw Agricultural, Fuel, Metal
- Other data: Commodity exchange rate (IMF); Global economic activity index (Kilian, 2009); oil production (US EIA), grain production (US Department of Agriculture), Steel production (World Steel Organisation)

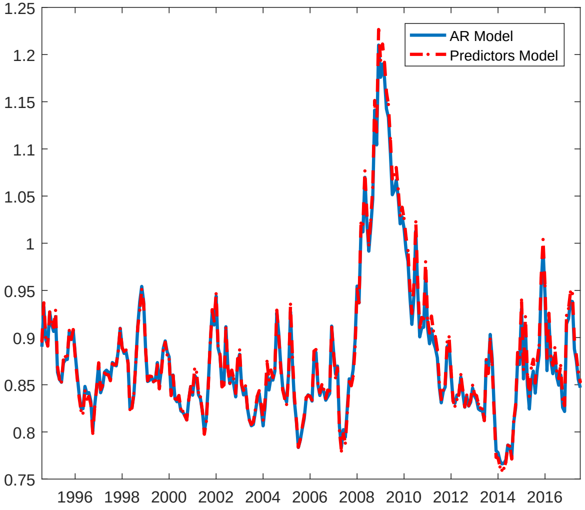
Data and empirical implementation

- **Baseline predictive model:** AR(4) model of each individual commodity price series i.e, measure uncertain each individual price series is to its past prices.

$$y_{jt+1} = \phi_{jt} y_{jt} + \upsilon_{j,t+1}$$

- Additional predictors do not improve predictability (exchange rate, production quantity, global economic activity index, commodity-group specific common component)

Commodity uncertainty with extra predictors

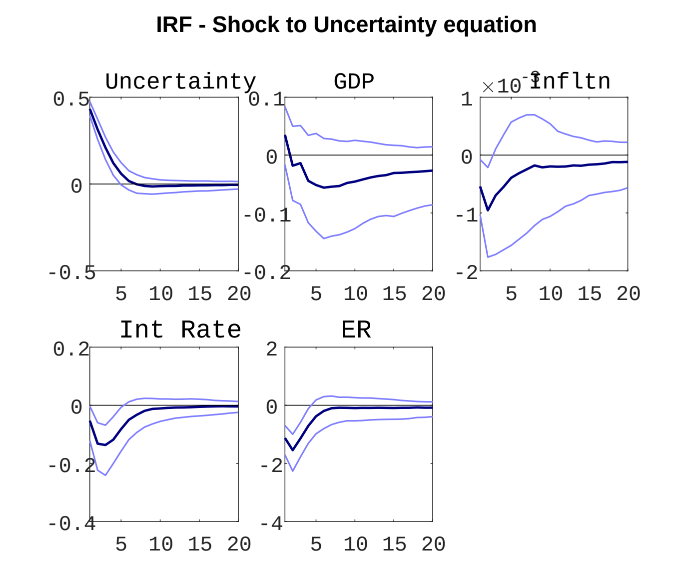


VAR evidence

$$X_t = \Phi(L)X_{t-1} + \epsilon_t$$

- $X_t = [U_t, GDP_t, \pi_t, r_t, e_t]'$,
- Recursive identification due to the assumption that global commodity price uncertainty shocks are exogenous to small open economies
- Include equation-specific constants and linear trends
- Sample 1994Q3 - 2017Q2

Australia



IRF - Shock to Uncertainty equation
Uncertainty
GDP
×10⁻³ Infltn
Int Rate
ER
0.5
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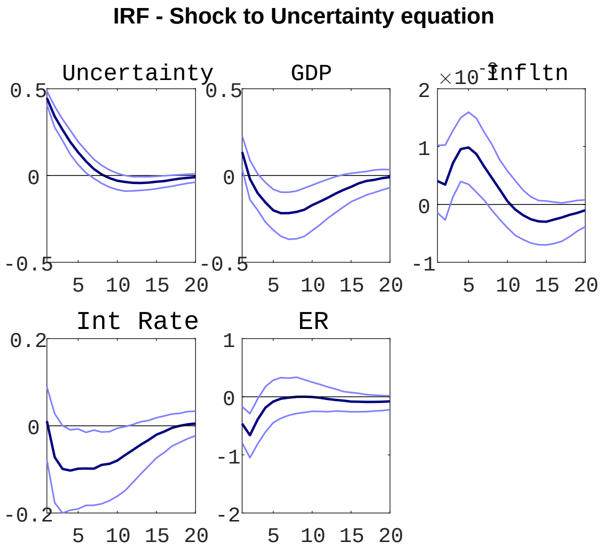
5 10 15 20

Canada


IRF - Shock to Uncertainty equation
Uncertainty
GDP
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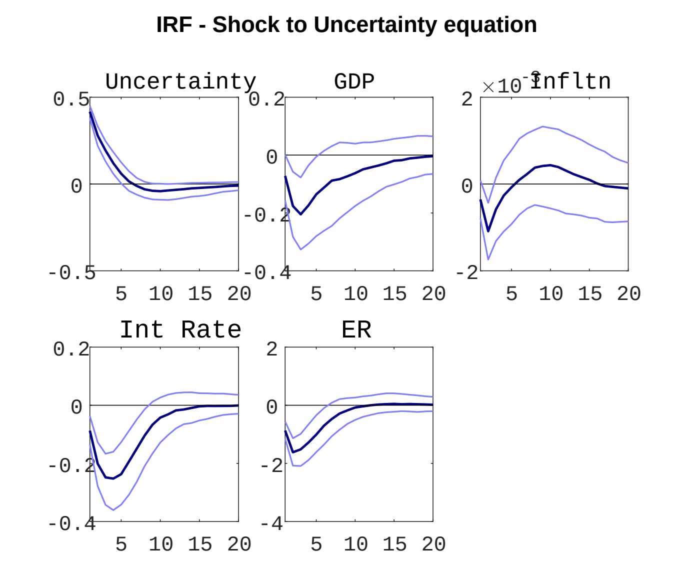
New Zealand


IRF - Shock to Uncertainty equation
Uncertainty
GDP
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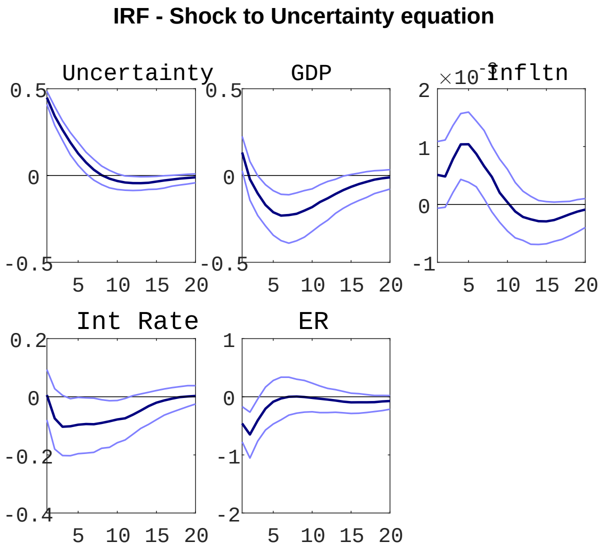
Norway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Int Rate
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5 10 15 20

Results

- Moderate impact of commodity price uncertainty on Australian variables. The results are similar to Moore (2016) and Castelnuovo & Tran (2017)
- Results on Canada, Norway and NZ are consistent with literature (Kamber et. al, 2016; Stockhammar & Österholm, 2017)
- Robust to: Controlling for commodity price (first moment shock), different lags, uncertainty being placed last

Top 5 commodity exports for selected countries

Australia	**Canada**
Mineral inl. Oils (29.1 %)	Mineral inl. Oils (20.1%)
Ores, slag, ash (26.2%)	Gems, precious metals (4.4%)
Gems, precious metals (6.7%)	Wood (3.3 %)
Meats (4%)	Alumium (2.3 %)
Cereals (2.9%)	Oil seeds (1.9 %)

New Zealand	**Norway**
Dairy, eggs, honey (27.6%)	Mineral inl. Oils (53%)
Meat (12.7%)	Fish (11.8%)
Wood (9%)	Aluminum (3.6%)
Fruits, nuts (5.1%)	Iron/steel (1.3%)
Beveridge (3.7%)	Organic chemical (1.2%)

Multisector model to explain transmission mechanism

- SOE framework with a commodity sector, a non-commodity tradable sector and non-traded sector
- Domestic commodity producer takes world price and world price uncertainty as given
- Representative household owns monopolistic firms in the domestic intermediate sectors
- Final good exporter sells domestically and internationally

Household sector

- Utility function

$$U = E_0 \sum_{t=0}^{\infty} \beta^t \xi_t \left[\frac{ln(C_t - hC_{t-1})^{1-\sigma}}{1-\sigma} - \frac{H_t^{1+\rho}}{1+\rho} \right] \quad (3)$$

- Budget constraint:

$$\begin{aligned} & P_t C_t + P_t I_t + \frac{B_t}{R_t} + S_t \frac{B_t^*}{R_t^*} + \frac{\Phi_D}{2} S_t \left(\frac{B_t^*}{R_t^*} - \frac{B^*}{R^*} \right)^2 \\ & \leq \sum_{j=n,m,z} (W_{j,t} H_{j,t} + R_{j,t} K_{j,t}) + B_{t-1} + S_t B_{t-1}^* + \Gamma_t \end{aligned} \quad (4)$$

- Investment adjustment costs:

$$K_{j,t+1} = (1-\delta)(K_{j,t}) + \Upsilon_t \left[1 - \frac{\Phi_K}{2} \left(\frac{I_{j,t}}{I_{j,t-1}} - 1 \right)^2 \right] I_{j,t} \quad (5)$$

The commodity sector

- Produces homogeneous output in a perfectly competitive market:

$$Y_{Z,t} = z_{Z,t} K_{Z,t}^{\alpha_Z} H_{Z,t}^{1-\alpha_Z} \tag{6}$$

- Commodity producers take prices as given. Foreign demand at $P^*_{Z,t}$. Assuming the law of one price holds:

$$P_{Z,t} = S_t P^*_{Z,t} \tag{7}$$

- In evidence of time-varying commodity price uncertainty:

$$\left(\frac{P^*_{Z,t}}{P^*_t}\right) = (1-\rho_Z)\left(\frac{P^*_Z}{P^*}\right) + \rho_Z\left(\frac{P^*_{Z,t-1}}{P^*_{t-1}}\right) + \exp(\sigma_{Z,t}) e_{Z,t}\ , e_{Z,t} \sim \mathrm{N}(\tag{8}$$

$$\sigma_{Z,t} = (1-\rho_{\sigma_Z})\sigma_Z + \rho_{\sigma_Z}\sigma_{Z,t-1} + \kappa u_t, u_t \sim \mathrm{N}(0,1) \tag{9}$$

Non-traded sector

- A continuum of monopolistically competitive non-traded firms

$$Y_{N,t} = \left(\int_0^1 Y_{N,t}(i)^{\frac{\epsilon-1}{\epsilon}} di \right)^{\frac{\epsilon}{\epsilon-1}} \quad (10)$$

- Expenditure minimisation yields:

$$Y_{N,t}(i) = \left(\frac{P_{N,t}(i)}{P_{N,t}} \right)^{-\epsilon} Y_{N,t} \quad (11)$$

- Producing according to:

$$Y_{N,t}(i) = z_{N,t}(K_{N,t}(i))^{\alpha_N} H_{N,t}^{1-\alpha_N} - \Psi_N \quad (12)$$

- Firms face staggered price setting following Calvo (1983). $1-\theta_N$ can change prices, $0 < \theta_N < 1$ can index their prices by past inflation.
- Indexation $\chi \in [0, 1]$, where $\chi = 0$ is no indexation and $\chi = 1$ is total indexation.

Non-commodity tradable sector

- The transformation of each firm's intermediate good follows the CES function for $k = D, X$

$$Y^k_{M,t} = \left[\int_0^1 Y^k_{M,t}(i)^{\frac{\epsilon-1}{\epsilon}} di\right]^{\frac{\epsilon}{\epsilon-1}} \tag{13}$$

- The demand functions for each firm's output

$$Y^k_{M,t}(i) = \left(\frac{P_{M,t}(i)}{P_{M,t}}\right)^{-\epsilon} Y^k_{M,t} \tag{14}$$

- Each firm produces:

$$Y_{M,t}(i) = z_{M,t}(K_{M,t}(i))^{\alpha_M} H^{1-\alpha_M}_{M,t} - \Psi_M \tag{15}$$

- Subject to Calvo pricing $1 - \theta_M$

The Import sector

- The output of the import sector is an aggregate constructed from a continuum of imported varieties
- Import at $S_t P_t^*$
- Sell domestically at price $P_{F,t}(i)$.
- The demand function for each variety i is:

$$Y_{F,t}(i) = \left(\frac{P_{F,t}(i)}{P_{F,t}} \right)^{-\epsilon} P_{F,t} \tag{16}$$

- Importing firms face staggered price setting $1 - \theta_F$

The Final Goods Sector

- Final good:

$$X_t = \left[(1-\omega_N)^{\frac{1}{\eta}} Y_{T,t}^{\frac{\eta-1}{\eta}} + \omega_N^{\frac{1}{\eta}} Y_{N,t}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{1-\eta}} \tag{17}$$

where

$$Y_{T,t} = \left[(1-\omega_F)^{\frac{1}{\nu}} Y_{M,t}^{\frac{\nu-1}{\nu}} + \omega_F^{\frac{1}{\nu}} Y_{F,t}^{\frac{\nu-1}{\nu}} \right]^{\frac{\nu}{\nu-1}} \tag{18}$$

- Representative firm's profit maximisation yields the following demand functions:

$$Y_{M,t} = (1-\omega_F) \left(\frac{P_{M,t}}{P_{T,t}} \right)^{-\nu} Y_{T,t} \tag{19}$$

$$Y_{F,t} = \omega_F \left(\frac{P_{F,t}}{P_{T,t}} \right)^{-\nu} Y_{T,t} \tag{20}$$

- The final goods price index is:

$$P_t = \left[(1-\omega_N)P_{T,t}^{1-\eta} + \omega_N P_{N,t}^{1-\eta}\right]^{\frac{1}{1-\eta}} \tag{21}$$

- and the price index of the tradable goods is:

$$P_{T,t} = \left[(1-\omega_F)P_{M,t}^{1-\nu} + \omega_F P_{F,t}^{1-\nu}\right]^{\frac{1}{1-\nu}} \tag{22}$$

Monetary Policy

The domestic central bank follows a Taylor rule that responds to inflation, output growth and real exchange rate:

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\rho_R} \left[\left(\frac{\Pi_t}{\Pi}\right)^{\phi_\pi} \left(\frac{Y_t}{Y_{t-1}}\right)^{\phi_Y} \left(\frac{Q_t}{Q}\right)^{\phi_Q}\right]^{1-\rho_R} \tag{23}$$

Market clearing

$$X_t = C_t + I_t \tag{24}$$

$$Y_{M,t} = Y_{M,t}^D + Y_{M,t}^X \tag{25}$$

$$Y_{M,t} = \frac{z_{M,t} K_{M,t}^{\alpha_M} H_{M,t}^{1-\alpha_N} - \Psi_M}{\Theta_{M,t}} \tag{26}$$

$$Y_{N,t} = \frac{z_{N,t} K_{N,t}^{\alpha_N} H_{N,t}^{1-\alpha_N} - \Psi_N}{\Theta_{N,t}} \tag{27}$$

By the properties under Calvo pricing:

$$\Theta_{j,t} = \theta_j \left(\frac{\Pi_{t-1}^{\chi}}{\Pi_t} \right)^{-\epsilon} \Theta_{j,t-1} + (1 - \theta_j) \dddot{\Pi}_t{}^{-\epsilon} \tag{28}$$

Market clearing (cont)

Nominal GDP is given by:

$$NGDP_t = P_{N,t}Y_{N,t} + P_{M,t}Y_{M,t} + P_{Z,t}Y_{Z,t} \tag{29}$$

And Real GDP is:

$$Y_t = \frac{P_{N,t}}{P}Y_{N,t} + \frac{P_{M,t}}{P}Y_{M,t} + \frac{P_{Z,t}}{P}Y_{Z,t} \tag{30}$$

The hours worked index includes hours allocated to the non-traded, non-commodity tradable and commodity sectors,

$$H_t = \left[H_{N,t}^{1+\phi_s} + H_{M,t}^{1+\phi_s} + H_{Z,t}^{1+\phi_s}\right]^{\frac{1}{1+\phi_s}} \tag{31}$$

Foreign economy, the current account and the exogenous process

$$\ln \frac{R_t^*}{R^*} = \rho_{R^*} \ln \frac{R_{t-1}^*}{R^*} + \epsilon_{R^*} \tag{32}$$

$$\ln \frac{\Pi_t^*}{\Pi^*} = \rho_{\Pi^*} \ln \frac{\Pi_{t-1}^*}{\Pi^*} + \epsilon_{\Pi^*} \tag{33}$$

$$\ln \frac{Y_t^*}{Y^*} = \rho_{Y^*} \ln \frac{Y_{t-1}^*}{Y^*} + \epsilon_{Y^*} \tag{34}$$

Foreign demand for domestic good is:

$$Y^X_{M,t} = \omega_{N^*} \left(\frac{P_{H,t}}{S_t P^*_t} \right)^{-\eta*} Y^*_t \tag{35}$$

Net export is:

$$NX_t = P_{M,t} Y^X_{M,t} + P_{Z,t} Y_{Z,t} - S_t P^*_t Y_{F,t}$$

And the current account is:

$$\frac{S_t B^*_t}{R^*_t} = S_t B^*_{t-1} + \frac{\Phi_D}{2} S_t \left(\frac{B^*_t}{R^*_t} - \frac{B^*}{R^*} \right)^2 + NX_t$$

All other structural shocks that following first-order autoregressive processes evolve according to:

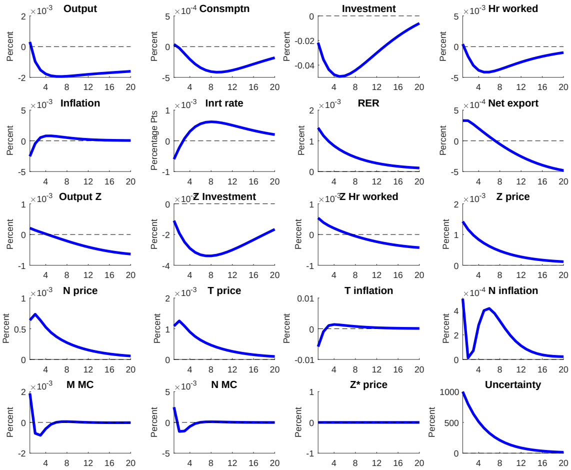
$$\varsigma_t = \rho_{\varsigma,t} \varsigma_{t-1} + \epsilon_{\varsigma,t}, \quad \epsilon_{\varsigma,t} \sim \mathrm{N}(0, \sigma^2_\varsigma) \tag{36}$$

where $\varsigma = \{\xi_t, \Upsilon_t, z_{M,t}, z_{N,t}, z_{Z,t}\}$

Solution Method

- Primary focus is examining the effect of an increase in second moment of the commodity price process
- Use Dynare to compute the rational expectation solutions to the model using third-order approximation
- First check, calibrate using steady-state relationship or results from previous studies

Model-implied impact of uncertainty



Conclusion and next step

- This paper
  1. Novel measure of commodity price uncertainty
  2. Significant impact of commodity price on real economic activity in both data and model
- Next step
  1. Find relevant set of commodity price uncertainty for those country
  2. Uncertainty is more volatile in recent period: TVP-VAR
  3. Linking the data and theory by estimating key parameters using VAR-DSGE impulse responses matching technique