Does demand noise matter? Identification and implications

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Introduction

Motivation

- Expectations as important drivers of economic fluctuations.
- Agents receive **noisy signals** about fundamental shocks, generating **waves of pessimism and optimism** among firms and consumers. **Misperception** about the true realization might be source of fluctuations.
- This paper disentangles demand and supply (noise) shocks

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- Theoretical literature has focused on narrowly-defined shocks, esp. **noise on productivity**:
  - **Noise shocks on productivity behave like demand shocks** (Lorenzoni, 2009)
- The empirics has also focused on supply-related noise
  - Blanchard et al. (2013), Forni et al. (2013), Enders et al. (2018), Barsky and Sims (2012), Angeletos et al. (2018), Fève and Guay (2018) and Chahrour and Ulbricht (2018).
- In reality, we might suspect that noisy signal are involved for **other fundamental shocks (like demand shocks)**
  - We should allow for **noise on demand**
  - Both consumers and firms might have a signal-extraction problem
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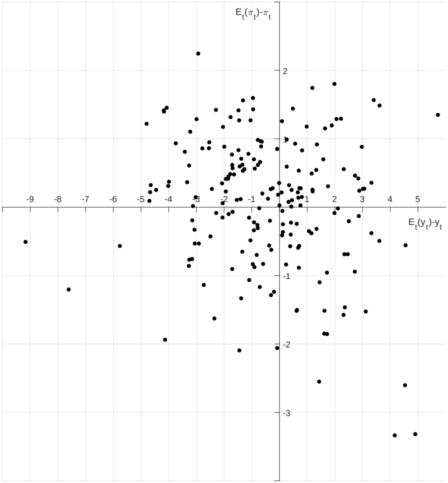
Figure: GDP growth and inflation: Nowcast errors of SPF (in p.p)



Contribution

- *Methodological contribution*:
  - Identification of multiple noise shocks (here:supply and demand) using sign restrictions on errors (here: errors on output and errors on inflation)
  - Assume surveyors are internally consistent
- *Empirical contribution*:
  - Evaluate the contribution of noise to fluctuations
    - Contribution of supply noise in small
    - Contribution of demand noise in large
  - Examine the effect of demand noise
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  - How to interpret our results?
    - Role of monetary policy
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Identifying noise shocks using sign restrictions

Sign and long-run restrictions

Shocks \ Var.	y_t	π_t	$\mathrm{E}_t y_t - y_t$	$\mathrm{E}_t \pi_t - \pi_t$
Supply	$+$	-		
	(permanently)			
Supply noise				
Demand	$+$	$+$		
Demand noise				

Can we use restrictions on errors to identify noise shocks as well?

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Can we use restrictions on errors to identify noise shocks as well?

- We use a reduced-form model to show how one can disentangle supply noise and demand noise shocks using *survey* expectation errors.
  $\Rightarrow$ Allows us to build our set of sign restrictions
- Assumptions needed for the use of sign restrictions:
  - Agents' (decision-makers') and surveyors' signals are affected by the same aggregate noise
  - Agents have private information
  - Surveyors are internally consistent (rational expectations)

A reduced-form model

- Consider an economy where output is driven by a demand shock $\epsilon_t \sim N(0, \sigma)$:

$$y_t = \epsilon_t$$

- Firm $i \in [0,1]$ sets her price in order to satisfy $p_{it} = \kappa E^f_{it}(y_t) = \kappa E^f_{it}(\epsilon_t)$, so that the aggregate price is:

$$p_t = \int_0^1 p_{it} di = \kappa \int_0^1 E^f_{it}(\epsilon_t) di$$

A reduced-form model

- Suppose firms receive a public signal s_t:

$$s_t = \epsilon_t + e_t$$

$e_t \sim \mathcal{N}(0, \sigma_0)$ is an aggregate noise shock

- and a private signal x_{it}:

$$x_{it} = \epsilon_t + \lambda_{it}$$

$\lambda_{it} \sim N(0, \sigma_1)$ is an idiosyncratic noise shock, with $\int_0^1 \lambda_{it} di = 0$.

- Firms form expectations rationally:

$$E_{it}^f(\epsilon_t) = \delta_0^f s_t + \delta_1^f x_{it}$$

$0 < \delta_0^f < 1$ and $0 < \delta_1^f < 1$ are the associated Bayesian weights

- Average prices:

$$p_t = \kappa \int_0^1 E_{it}^f(\epsilon_t) di = \kappa(\delta_0^f s_t + \delta_1^f \epsilon_t)$$

A reduced-form model

- Output and inflation:

$$\begin{aligned} y_t &= \epsilon_t \\ p_t &= \kappa \int_0^1 E_{it}^f(\epsilon_t) di = \kappa(\delta_0^f s_t + \delta_1^f \epsilon_t) = \kappa[\delta_0^f e_t + (\delta_0^f + \delta_1^f)\epsilon_t] \end{aligned}$$

- Consider now a **surveyor** who forms expectations about p_t. For simplicity, assume that he observes only the public signal s_t (no private information).
- Using $E_t^s(\epsilon_t) = \delta_0^s s_t$ and $E_t^s(s_t) = s_t$, we obtain

$$\begin{aligned} E_t^s(y_t) - y_t &= E_t^s(\epsilon_t) - \epsilon_t = \delta_0^s s_t - \epsilon_t = \delta_0^s e_t - (1 - \delta_0^s)\epsilon_t \\ E_t^s(p_t) - p_t &= \kappa\delta_1^f [E_t^s(\epsilon_t) - \epsilon_t] = \kappa\delta_1^f [\delta_0^s s_t - \epsilon_t] = \kappa\delta_1^f [\delta_0^s e_t - (1 - \delta_0^s)\epsilon_t], \end{aligned}$$

where δ_0^s is the Bayesian weight associated with the surveyor's information.

- If the fundamental shock drives a positive correlation between output and prices ($\kappa > 0$), then both the fundamental and noise shocks drive a positive correlation between the errors.

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Supply noise			+	-
Demand	+	+	-	-
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We need some restrictions that distinguish supply and demand noise shocks from negative supply and demand shocks

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Empirical Analysis

Objective

- Now that we can distinguish all these shocks through their effect on output, inflation and nowcast errors:
  - Empirical analysis to assess the **effect and contribution of noise shocks to business cycle**.

Methodology

- Estimate the following **canonical VAR** model with 8 lags on US data over 1969q2-2017q1:

$$Y_t = \Phi(L)\, Y_t + \varepsilon_t$$

with

$$Y_t = \left(\Delta y_t,\ \pi_t,\ E_t\Delta y_t - \Delta y_t,\ E_t\pi_t - \pi_t\right)'$$

where Δy_t: output growth, π_t: inflation in annualized percent change (GDP deflator), $(E_t\Delta y_t - \Delta y_t)$ and $(E_t\pi_t - \pi_t)$: nowcasts errors computed as difference between nowcast prediction from Survey of Professional Forecasters and first release of Δy_t and π_t.

Methodology

- Canonical innovations, ε_t, are related to **structural innovations**, ξ_t, by the following linear combination

$$\varepsilon_t = \Gamma \xi_t$$

  where structural shocks are by assumption orthogonalized, such that $\xi_t \sim iid(0, I_{n \times n})$ and Γ is a $(n \times n)$ non singular matrix.

$\Rightarrow$ Impose **long-run and sign restrictions** on Γ by using predictions from the model.

more

Sign and long-run restrictions

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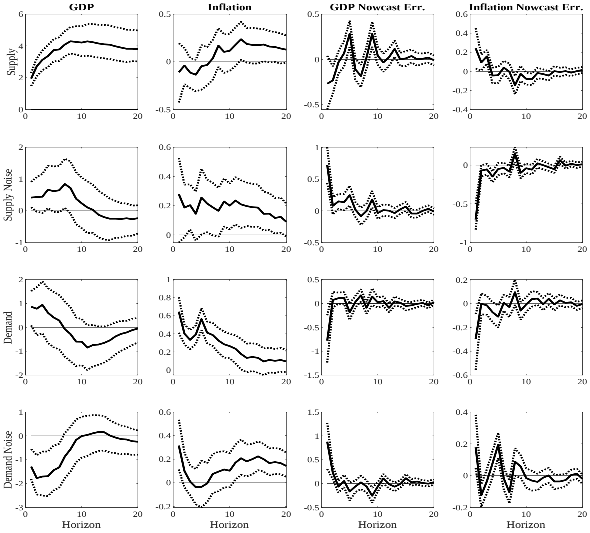
Supply noise	+		+	-
Demand		+	-	-
Demand noise		+	+	+

Results: IRFs on output and inflation



Results: Variance decomposition

Baseline estimation: Unconditional variance decomposition.

	Supply	Supply noise	Demand	Demand noise
GDP growth	0.44 [0.31,0.58]	0.09 [0.05,0.15]	0.17 [0.09,0.30]	0.24 [0.11,0.40]
Inflation	0.17 [0.07,0.39]	0.18 [0.04,0.42]	0.37 [0.17,0.60]	0.14 [0.07,0.31]
GDP Nowcast err.	0.15 [0.10,0.23]	0.22 [0.13,0.34]	0.25 [0.12,0.46]	0.30 [0.13,0.51]
Infl. Nowcast err.	0.16 [0.09,0.28]	0.46 [0.27,0.62]	0.15 [0.07,0.33]	0.15 [0.09,0.23]

Note: For each successful draw, the unconditional variance decomposition is computed. The upper number reports the median value and numbers under brackets are the 16th and 84th percentile values of the variance decomposition distribution.

Robustness ▸ IRFs ▸ more

Robustness: Output growth unconditional variance decomposition

	Supply	Supply noise	Demand	Demand noise
(a) Benchmark	0.44 [0.31,0.58]	0.09 [0.05,0.15]	0.17 [0.09,0.30]	0.24 [0.11,0.40]
(b) Relax noise supply	0.44 [0.31,0.57]	0.10 [0.05,0.18]	0.16 [0.09,0.28]	0.25 [0.12,0.40]
(c) Relax noise demand	0.44 [0.32,0.58]	0.09 [0.05,0.16]	0.17 [0.09,0.32]	0.23 [0.10,0.40]
(d) Sign restr. only	0.47 [0.33,0.59]	0.10 [0.06,0.18]	0.17 [0.09,0.30]	0.21 [0.11,0.35]
(e) Great Moderation	0.28 [0.18,0.41]	0.17 [0.10,0.29]	0.30 [0.17,0.44]	0.19 [0.12,0.31]
(f) 12 Lags	0.43 [0.27,0.56]	0.14 [0.09,0.22]	0.17 [0.12,0.27]	0.20 [0.11,0.35]
(*g*) Mean Nowcast	0.46 [0.33,0.57]	0.14 [0.09,0.21]	0.18 [0.12,0.26]	0.18 [0.12,0.28]
(*h*) Three-variables SVAR	0.70 [0.50,0.82]	0.09 [0.5,0.19]	0.19 [0.10,0.34]	—

Structural Interpretation of the Results

Model

- Bare-bones **New Keynesian model** with Calvo pricing
- Agents:
  - Continuum of firms, continuum of households, a central bank
- A continuum of surveyors.
- Economy-wide fundamental shocks:
  - TFP shock (=**supply shock**)
  - Preference shock (=**demand shock**)

Households

- *Household i* maxime

$$U_{it} = E_t \sum_{s=0}^{\infty} B_{t+s} \left\{ \log(C_{it+s}) - \frac{1}{1+\zeta} N_{it+s}^{1+\zeta} \right\},$$

where $B_t = \beta B_{t-1} e^{-u_{t-1}^b}$ and u_t^b is the **preference shock** such that

$$u_t^b = \rho_b u_{t-1}^b + \epsilon_t^b, \qquad with\ \epsilon_t^b \sim iid(0,\sigma_b^2).$$

The budget constraint is

$$\begin{aligned} & i_t D_{it+1} + P_{I_{it}^s t} C_{it} + \int Q(\omega_{it}) Z_{it+1}(\omega_{it}) d\omega_{it} \\ = \quad & D_{it} + W_{I_{it}^w t} N_{it} + \int_0^1 P_{ijt} Y_{ijt} dj + Z_{it}(\omega_{it-1}). \end{aligned}$$

Production sector

- *Final good sector:*
  - , A competitive firm combines a continuum of intermediate goods $Y_{i,t}$, with $i \in [0,1]$, to produce the final good, Y_t following

$$Y_t = \left(\int_0^1 Y_{it}^{(\gamma-1)/\gamma} di \right)^{\gamma/(\gamma-1)} .$$

- *Intermediate good sector:*
  - Production function of firm $i \in [0,1]$:

$$Y_{it} = A_t N_{it},$$

where $A_t = \bar{A} e^{u_t^a}$, where u_t^a is the **productivity shock**, such that

$$u_t^a = u_{t-1}^a + \epsilon_t^a, \quad \text{with } \epsilon_t^a \sim iid(0,\sigma_a^2).$$

  - Calvo price-setting: each period, a firm faces a probability $1-\theta$ of being able to re-optimize its price.

Monetary policy

- The *central bank* set the nominal interest rate such that

$$i_t = \bar{\imath} + \varphi E_t^g(\pi_t),$$

where $E_t^g(\cdot)$ denotes the expectations of the central bank.

Information

- Each period t, agents learn past shocks: u^a_{t-1} and u^b_{t-1}.
- Economy-wide **public signals**:

$$\text{public signal on supply} \quad : \quad s^a_t = u^a_t + e^a_t,$$
$$\text{on demand} \quad : \quad s^b_t = u^b_t + e^b_t$$

with $e^a_t \sim \mathcal{N}(0, (\sigma^a_0)^2)$ and $e^b_t \sim \mathcal{N}(0, (\sigma^b_0)^2)$

- Additionally:
  - Firm $i \in [0, 1]$ observes u^a_t and the private signal $x^{bf}_{it} = u^b_t + \lambda^{bf}_{it}$, $\lambda^{bf}_{it} \sim \mathcal{N}(0, \sigma^f_{b1})$.
  - Household $i \in [0, 1]$ observes u^b_t and private signal $x^{ac}_{it} = u^a_t + \lambda^{ac}_{it}$, $\lambda^{ac}_{it} \sim \mathcal{N}(0, \sigma^c_{a1})$.
  - The central bank observes public signals only.
  - Surveyor $i \in [0, 1]$ observes the private signals $x^{bs}_{it} = u^b_t + \lambda^{bs}_{it}$, $\lambda^{bs}_{it} \sim \mathcal{N}(0, \sigma^s_{b1})$ and $x^{as}_{it} = u^a_t + \lambda^{as}_{it}$, $\lambda^{as}_{it} \sim \mathcal{N}(0, \sigma^s_{a1})$.
  - Agents learn past aggregate shocks after T periods.

Limit case

In a limit case where $T = 1$ and $\rho_b = 0$:

- **Aggregate Euler equation**

$$y_t = \bar{E}_t^c \{y_{t+1} + \pi_{t+1}\} - \varphi E_t^g \{\pi_t\} + u_t^b$$

u_t^b is a demand shifter. Aggregate demand depends on the average households' expectations.

- **Aggregate Phillips curve**

$$\pi_t \quad = \quad \kappa \left(\bar{E}_t^f \{y_t\} - u_t^a \right) + \tfrac{1-\theta}{\theta} \left(\bar{E}_t^f \{\pi_t\} - \pi_t \right)$$

u_t^a is a supply shifter (ie capacity output). Aggregate inflation depends on the average firms' expectations.

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Model's predictions (limit case)

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Supply noise	+	+	+	-
Demand	+	+	-	-
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- **Supply noise shock has same effect as a demand shock**
- **Demand noise shock has same effects as a supply shock** intermediate input
- **Validates our sign restriction strategy** analytical results simulations

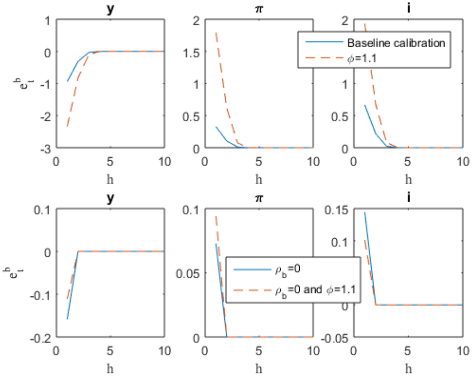
Estimating the model

- We fix the standard parameters ($\theta = 0.65$, $\beta = 0.99$, $\varphi = 2$, $\zeta = 1$, $\rho_b = 0.9$)
- Estimate the other parameters (information-related parameters) by Minimum-Distance Estimation (MDE): We minimize the distance between theoretical and empirical moments (conditional standard deviations), weighted by their empirical variance.

$\Rightarrow$ Sizeable conditional expectation errors $\leftrightarrow$ non-negligible amount of private information more

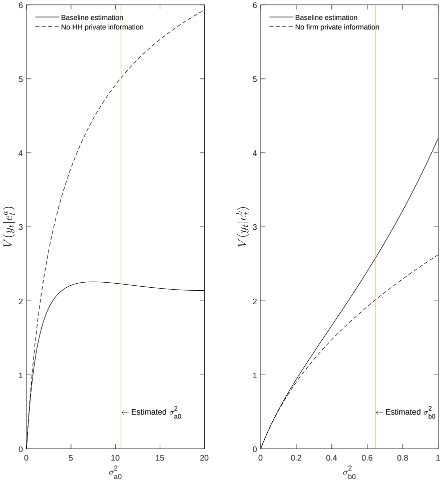
$\Rightarrow$ Why is the contribution is supply noise small and the contribution of demand noise large?

Understanding the effect of demand noise



- A **weaker monetary policy** amplifies the negative effects of demand noise shocks when demand shocks are persistent.
- Consistent with milder effect of noise shocks in the post-Volcker era ▸ IRFs

The firm information paradox



Conclusion

Conclusion

- **Use forecast errors to identify fundamental and noise shocks**
- **What is the effect of demand noise shocks**?
  - Recessionary
  - Potentially important role of monetary policy
- **How much of economic fluctuations are explained by noisy signals about the true state of the economy**?
  - Demand noise shocks contribute to 25% of GDP growth
  - Supply noise contributes to about 10%
- **Pervading role of information frictions**

Output and inflation

Lemma

Under exogenous information and $\rho_b = 0$, the equilibrium output and inflation are

$$\begin{aligned} y_t &= u^a_{t-1} + \delta_{0a} s^a_t && - \tfrac{\kappa\varphi\delta_{0b}}{1+\kappa\varphi} s^b_t + \epsilon^b_t \\ &= u^a_{t-1} + \delta_{0a}(\epsilon^a_t + e^a_t) && - \tfrac{\kappa\varphi\delta_{0b}}{1+\kappa\varphi} e^b_t + \tfrac{1}{1+\kappa\varphi} \epsilon^b_t \\ \pi_t &= \kappa \left[\delta_{0a} s^a_t - \epsilon^a_t\right] && + \tfrac{\kappa\delta_{0b}}{1+\kappa\varphi} s^b_t \\ &= \kappa \left[\delta_{0a} e^a_t - (1-\delta_{0a})\epsilon^a_t\right] && + \tfrac{\kappa\delta_{0b}}{1+\kappa\varphi} (\epsilon^b_t + e^b_t) \end{aligned}$$

with $0 < \delta_{0j} < 1$ for $j = a, b$.

▸ back

Expectation errors

Lemma 1 implies

$$\begin{aligned} \bar{E}_t^s y_t - y_t &= \delta_{1a}\left(\bar{E}_t^s \epsilon_t^a - \epsilon_t^a\right) + \bar{E}_t^s \epsilon_t^b - \epsilon_t^b \\ \bar{E}_t^s \pi_t - \pi_t &= \kappa\left[-(1-\delta_{1a})\left(\bar{E}_t^s \epsilon_t^a - \epsilon_t^a\right) + \frac{\theta\delta_{1b}}{1-(1-\theta)\delta_{1b}}\left(\bar{E}_t^s \epsilon_t^b - \epsilon_t^b\right)\right] \end{aligned}$$

with $\bar{E}_t^s \epsilon_t^j - \epsilon_t^j = -(1-\delta_{0j}-\delta_{1j})\epsilon_t^j + (\delta_{0j}+\delta_{1j})e_t^j$, with $0 < \delta_{0j}+\delta_{1j} < 1$.

back

Intermediate input

- **Intermediate input**: firms make quantity decisions
  - Demand noise can have a **positive** effect on output
  - Otherwise, same restrictions
- Production function:

$$Y_{it} = X_{it}{}^{\alpha}(A_t N_{it})^{1-\alpha},$$

with $0 < \alpha < 1$.

- Demand for intermediate input by firm i:

$$x_{it} = E^f_{it}(y_{it})$$

- Aggregate demand:

$$y_t = (1-\tau)c_t + \tau \bar{E}^f_t(c_t)$$

- **Effect on output ambiguous but effect on errors is the same.**

back

Sign Restrictions

- This relation can be re-written as

$$\Sigma = \Gamma\Gamma'$$

  Economic restrictions can be imposed on matrix Γ through sign restrictions

- How to select Γ?

$$\Gamma = \tilde{\Gamma} Q$$

  where $\tilde{\Gamma}$ is a Choleski decomposition of Σ and Q is an orthonormal matrix ($QQ' = I_{n\times n}$)

  - Build a Choleski decomposition $\tilde{\Gamma}$
  - Draw Q randomly
  - If $\Gamma = \tilde{\Gamma} Q$ satisfies the sign restrictions, then select Γ

Sign **and zero** Restrictions with **inference**

- We build on Arias, Rubio-Ramirez and Waggoner (2016)
  - Draw first $\hat{\Phi}(L)$ and $\hat{\Sigma}$ from their asymptotic distribution.
  - Find $\tilde{\Gamma}$ the Choleski decomposition of Σ:

$$\Sigma = \tilde{\Gamma}\tilde{\Gamma}'$$

  - Draw an orthonormal matrix Q that satisfies the zero restrictions randomly
  - If $\Gamma = \tilde{\Gamma}Q$ satisfies the sign restrictions, then select Γ
  - Do this K times

back

Checking validity of sign restrictions

back

We perform 10'000 simulations where parameters are drawn from:

	Parameter	Range	Parameter	Range
Baseline Model				
	σ_a^2	1	σ_b^2	1
	σ_{a0}^{-2}	$[0, 10]$	σ_{b0}^{-2}	$[0, 10]$
	$(\sigma_{a1}^c)^{-2}$	$[0, 10]$	$(\sigma_{b1}^f)^{-2}$	$[0, 10]$
	$(\sigma_{a1}^s)^{-2}$	$[0, 10]$	$(\sigma_{b1}^s)^{-2}$	$[0, 10]$
	$(\sigma_{a1}^g)^{-2}$	$[0, 10]$	$(\sigma_{b1}^g)^{-2}$	$[0, 10]$
	τ	$[0, 1]$	τ	$[0, 1]$
	ϕ	$[0, 1]$	ϕ	$[0, 1]$

We obtain:

Baseline Model	Δy_t	π_t	$\bar{E}_t^s(\Delta y_t) - \Delta y_t$	$\bar{E}_t^s(\pi_t) - \pi_t$
ϵ_t^a	> 0 (100)	< 0 (100)	< 0 (100)	> 0 (100)
e_t^a	> 0 (100)	> 0 (100)	> 0 (100)	< 0 (100)
ϵ_t^b	> 0 (100)	> 0 (100)	< 0 (100)	< 0 (100)
e_t^b	< 0 (91)	> 0 (98)	> 0 (100)	> 0 (100)

Checking validity of sign restrictions back

Adding Shocks Model				
ϵ_t^v	> 0 (100)	> 0 (100)	< 0 (100)	< 0 (100)
e_t^v	< 0 (61)	> 0 (100)	> 0 (100)	> 0 (100)
ϵ_t^g	> 0 (96)	> 0 (98)	< 0 (96)	< 0 (97)
e_t^g	< 0 (59)	> 0 (96)	> 0 (96)	> 0 (97)

Model with Temporary Supply Shocks				
ϵ_t^a	> 0 (100)	< 0 (100)	< 0 (100)	> 0 (100)
e_t^a	> 0 (100)	> 0 (100)	> 0 (100)	< 0 (100)
μ_t^a	> 0 (100)	< 0 (100)	< 0 (100)	> 0 (100)

Estimation results: supply

back

Table 8. Estimation results: Supply shocks

	Data	Baseline	No HH priv. info $(\sigma^c_{a1})^{-2} = 0$
Estimated parameters			
σ^2_a		6.8	5.2
σ^2_{a0}		8.8	2.0
$\sigma^{-2}_{a0}/\sigma^{-2}_a$		0.77	2.6
$(\sigma^c_{a1})^{-2}/\sigma^{-2}_a$		1.4	(constrained)
$(\sigma^s_{a1})^{-2}/\sigma^{-2}_a$		0.0038	0
J-stat		5.5 (0.73)	30 (0.01)

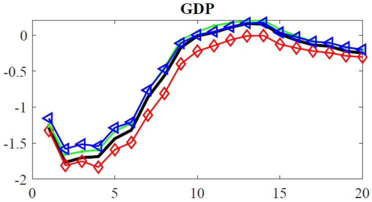
Estimation results: demand ‣ back

Table 9. Estimation results: Demand shocks

	Data	Baseline	No firm priv. info $(\sigma^f_{b1})^{-2} = 0$
Estimated parameters			
σ^2_b		0.69	0.75
σ^2_{b0}		0.52	0.70
$\sigma^{-2}_{b0}/\sigma^{-2}_b$		1.3	1.1
$(\sigma^f_{b1})^{-2}/\sigma^{-2}_b$		1.1	(constrained)
$(\sigma^s_{b1})^{-2}/\sigma^{-2}_b$		0.29	0.42
J-stat		5 (0.59)	12 (0.02)

Robustness ▸ back

Figure: IRFs to a demand-noise shock.



Note: On the left panel, the solid (black) line corresponds to the "baseline" case (*a*). The (red) line with diamond markers corresponds to the "relax supply noise" case (*b*). The (green) line with dot markers corresponds to the "relax demand noise" case (*c*). The (blue) line with lower-than symbol marker corresponds to the "sign restrictions only" case (*d*). On the right panel, the (brown) line with lower triangular markers corresponds to the "great moderation" case (*e*). The (purple) line with stars markers corresponds to the "12 lags" case (*f*). The (green) line with superior markers corresponds to the "third release" case (*g*). The (magenta) line with square markers corresponds to the "mean nowcast" case (*h*). The (yellow) line with lower-than symbol markers corresponds to the "three variables SVAR" case (*i*).

Robustness

back

Figure: Unconditional variance decomposition for several release horizons.

	Supply	Supply noise	Demand	Demand noise
Output Growth				
(a) Benchmark	0.44 [0.31,0.58]	0.09 [0.05,0.15]	0.17 [0.09,0.30]	0.24 [0.11,0.40]
(b) Second-release	0.39 [0.24,0.54]	0.14 [0.09,0.22]	0.19 [0.12,0.29]	0.22 [0.11,0.39]
(c) Third-release	0.42 [0.25,0.57]	0.13 [0.08,0.20]	0.19 [0.12,0.31]	0.19 [0.10,0.38]
(d) Most recent-release	0.49 [0.37,0.58]	0.14 [0.09,0.20]	0.21 [0.15,0.29]	0.15 [0.09,0.24]

IRfs to demand noise shocks - Role of the interest rate ▸ back