Large Macroeconomic shocks during the Pandemic: a DSGE analysis

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ABSTRACT

This paper estimates a DSGE model including the Covid-19 episode. To let the data speak about the diverse types of macroeconomic shocks caused by the pandemic, we build a Two-Sector One (Two)-Agent model and estimate it through Bayesian methods. The resulting **medium-scale New Keynesian model** includes the standard real and nominal frictions used in the empirical literature and allows for heterogeneous pandemic exposure across sectors. On account of the magnitude of the involved shocks, we solve the model **nonlinearly**. To conduct inference on the resulting non-linear non-Gaussian system, we employ a version of the **Cubature Kalman filter** suited to handle the large shocks and use the Sequential Monte Carlo sampler to obtain parameters draws from the posterior distribution. Large shocks pose questions about the way of modelling the interdependence between them, so we use a flexible specification that allows to distinguish between all possible combinations of disaster shocks. Results show that the pandemic-induced economic downturn can be reconciled with a combination of demand and supply factors.

INTRODUCTION

The unprecedented economic losses due to the COVID-19 pandemic require to take into account **nonlinearities** and **heterogeneity**.

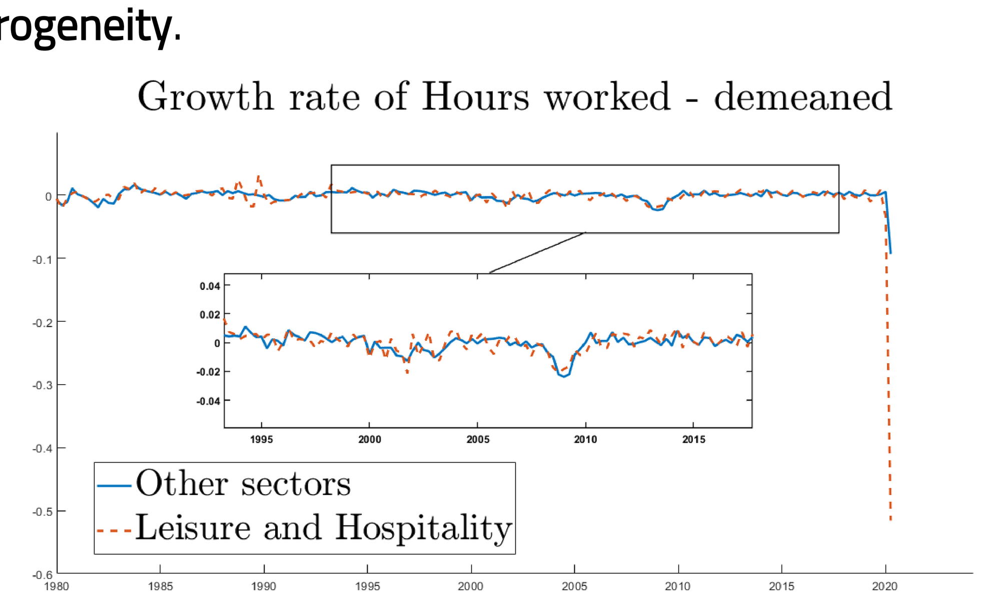


Figure 1

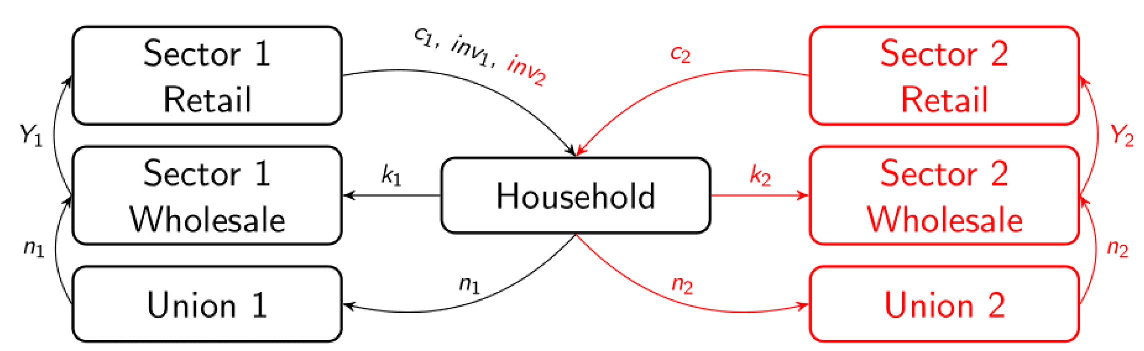
We divide the economy into the Leisure and Hospitality sector (Sector 2) and the rest of the economy (Sector 1).

We estimate the two-sectoral model on US data up to 2020:II.

11 observables: Value Added 1, Value Added 2, Hours 1, Hours 2, Federal Funds Rate, Aggregate investment, Aggregate Consumption, Inflation 1, Inflation 2, Wage Inflation 1 and Wage Inflation 2.

THE DSGE MODEL

The benchmark model is the One-Household Two-Sector model:



Sector 1 = Rest of the economy
Sector 2 = Leisure and Hospitality

Figure 2

- Nominal rigidities in price and wage adjustment in the two sectors
- Real rigidities on investment and capital utilization
- External habits

- **In the Two-Household Two-Sector version, labor supply is fully specialized between two families.**

A variety of supply and demand shocks is allowed:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \boldsymbol{a_{\zeta,t}} \Big[\frac{1-h_1}{1-\beta h_1} log(c_{1,t} - h_1 c_{1,t-1}) + \boldsymbol{a_{j,t}} \frac{1-h_2}{1-\beta h_2} log(c_{2,t} - h_2 c_{2,t-1}) - \boldsymbol{\phi_{1,t}} \frac{n_{1,t}^{1+\nu_1}}{1+\nu_1} - \boldsymbol{\phi_{2,t}} \frac{n_{2,t}^{1+\nu_2}}{1+\nu_2} \Big]$$

$$Y_{1,t} = (\boldsymbol{a_{z_{1},t}} n_{1,t})^{1-\alpha_1} (uk_{1,t} k_{1,t-1})^{\alpha_1}$$

$$Y_{2,t} = (\boldsymbol{a_{z_{2},t}} n_{2,t})^{1-\alpha_2} (uk_{2,t} k_{2,t-1})^{\alpha_2}$$

Large shocks: **Supply**

- Labor supply $\phi_{1,t}$ $\phi_{2,t}$
- Labor productivity $a_{z_1,t}$ $a_{z_2,t}$

Large shocks: **Demand**

- Intratemporal preference $a_{j,t}$
- Intertemporal preference $a_{\zeta,t}$

THE FILTERING PROBELM

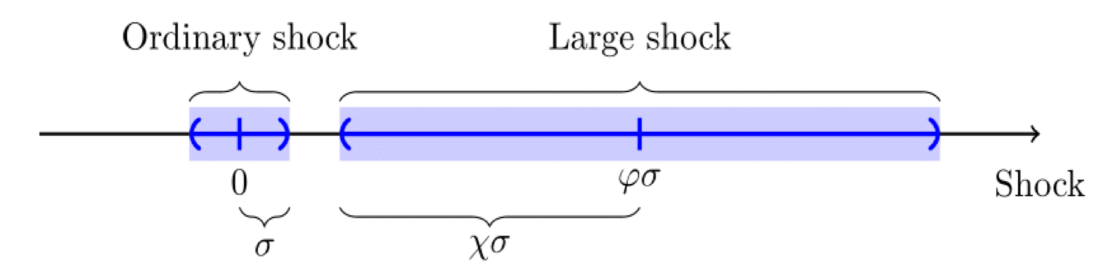


Figure 3

$$p(\epsilon_t^{std}) = \Big(1 - \sum_{i \in \mathcal{S}} p_i\Big) \mathcal{N}(\mathbf{0}, I) + \sum_{i \in \mathcal{S}} p_i \mathcal{N}(\varphi \cdot \boldsymbol{\iota_i}, \chi^2 \cdot diag(\boldsymbol{\iota_i}))$$

All the possible combinations of large and ordinary shocks are tested.

In addition to large shocks, nonlinearity stems from the **Zero Lower Bound**, which we model using a smooth nonlinear Taylor rule:

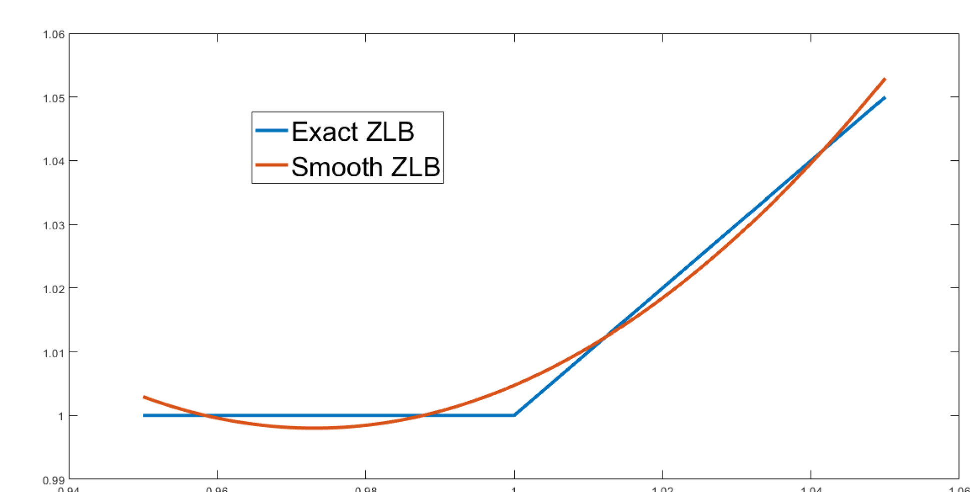


Figure 4

The model is solved by a second order perturbation.

26 state variables + large shocks:

A particle filter becomes hardly feasible.

We use a version of the Cubature Kalman Filter for non-Gaussian shocks: **Gaussian Sum Cubature Kalman Filter.**

Banks of Cubature Kalman filters run in parallel by making as many predictions as the number of possible large shocks combinations. Then ensemble weights are computed and the filters are merged.

$$w_t^n = \frac{p(\boldsymbol{y_t}|\boldsymbol{x_t}, n)\, w_{t-1}^n}{\sum_{j=1}^{GK} p(\boldsymbol{y_t}|\boldsymbol{x_t}, j)\, w_{t-1}^j} \qquad \hat{\boldsymbol{x}}_{t|t} = \sum_{n=1}^{GK} w_t^n \hat{\boldsymbol{x}}_{t|t}^n$$

$$P_{t|t} = \sum_{n=1}^{GK} w_t^n \Big[P_{t|t}^n + \Big(\hat{\boldsymbol{x}}_{t|t}^n - \hat{\boldsymbol{x}}_{t|t}\Big)\Big(\hat{\boldsymbol{x}}_{t|t}^n - \hat{\boldsymbol{x}}_{t|t}\Big)^{\mathrm{T}} \Big]$$

- In Engineering: Faubel et al. (2009), Leong et al. (2013).
- Closest application in Economics: Binning and Maih (2015).

ESTIMATION METHODOLOGY

The model is estimated with Bayesian methods.

The sequential Monte Carlo sampler (SMC) is used.

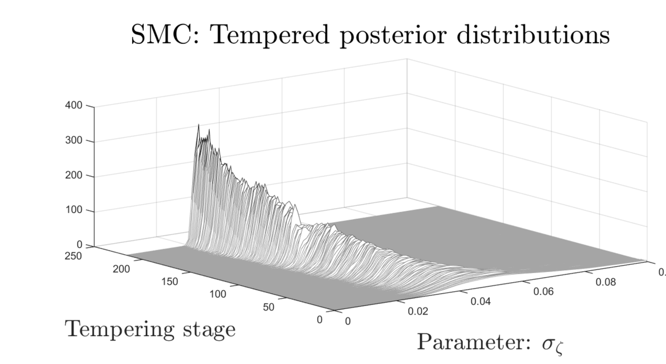


Figure 4

- In Economics: Creal (2007), Herbst and Schorfheide (2014).

RESULTS

The filter detects the following combination of large shocks at quarter 2020:II

- Labor supply Sector 1 ε_{t1}
- Sector 2 specific demand shock ε_j
- Labor productivity Sector 2 ε_{z2}
- General demand shock ε_ζ

The standardized large shocks are depicted in the following figure:

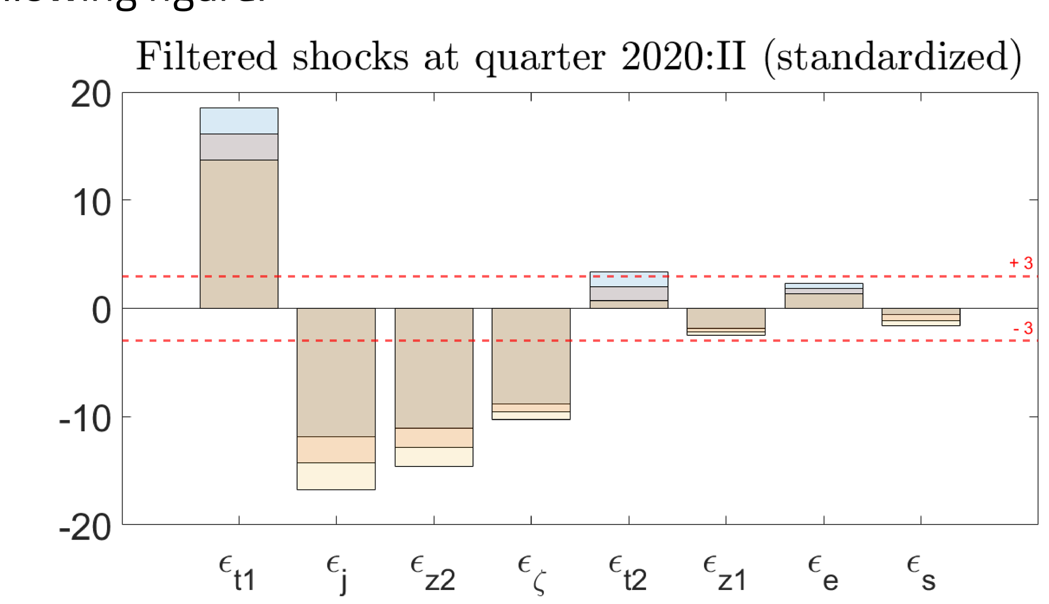


Figure 5

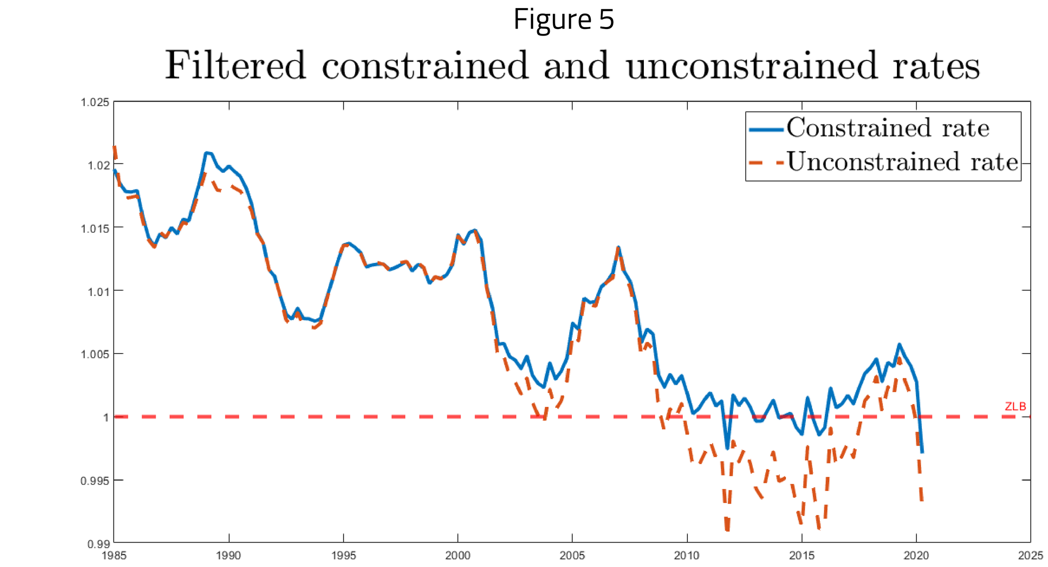


Figure 6

Pandemic-induced losses: **supply** and **demand** side.

Extensions:

- CES utility function
- Latest quarters.