What are the Driving Forces of the Economic Downturn during COVID-19?

Sanha Noh Ingul Baek

Jeonbuk National University

Kongju National University

Ajou University (Seminar presentation)

June 21st, 2022

Table of Contents

INTRODUCTION

Stylized Facts

Stylized facts in emerging countries

- High volatilities in Consumption and Output
- $\sigma(consumption) > \sigma(output)$
- Countercyclicality in Trade Balance
- Frequent Regime-Switching Behavior

Table 1: Business cycles in emerging countries

	All	Emerging	Rich	Argentina	Mexico	Korea	U.S.
σ_{Δ_y}	4.39	4.08	2.38	5.78	3.42	3.53	2.18
$\sigma_{\Delta_c}/\sigma_{\Delta_y}$	1.14	1.34	0.85	1.43	1.2	1.22	0.83
$\sigma_{tb/y}$	2.34	3.8	1.25	3.49	3.06	5.76	1.87
$corr(tb/y, \Delta y)$	-0.1	-0.2	-0.07	-0.21	-0.46	-0.21	0.05
$corr(tb/y, tb/y_{-1})$	0.61	0.62	0.69	0.67	0.76	0.81	0.94

Annual data from WDI (1965-2011), Martín Uribe (http://www.columbia.edu/ mu2166/book/empirics/)

Stylized Facts in Korea

- $\sigma(consumption) > \sigma(output)$
- Countercyclicality in Trade Balance-to-Output Ratio
- Stable than other Emerging Countries since Asian crisis (Argentina, Mexico, etc)
- Two downturns: 2008 Financial Crisis and recent COVID-19

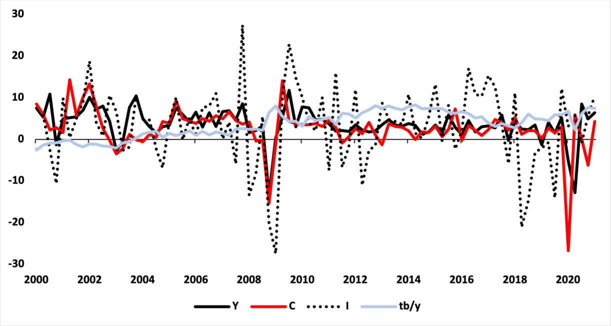


Figure 1: Business Cycles in Korea

Stylized Facts in Korea

- Downward trend of the relative price of imported intermediate goods

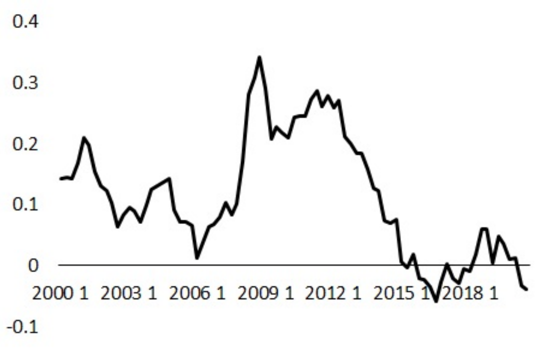


Figure 2: Relative price of imported intermediate goods

Beginning of the Tragedy

- Spread of the virus since Dec, 2019 from Wuhan, China
- WHO announced the Pandemic state since H1N1 flu 2009
- First patient in Korea on Jan 20th, 2020
- World: Total cases 219 million / Death 4.5 million
- Korea: Total cases 346K / Death 2,698

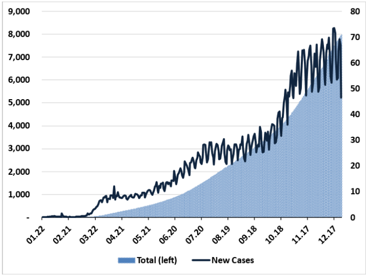


Figure 3: Outbreak of the Pandemic

Stylized Facts: During COVID-19

COVID-19 Shock ≈ Mixture of various Supply and Demand Shocks

- Lockdown measure → Disruption of Global Supply Chain
- Fear of Infection and social distancing → Restriction on Willingness to Consume

- Immediate Response of Consumption in 2020Q1
- Delayed decrease in Output in 2020Q2

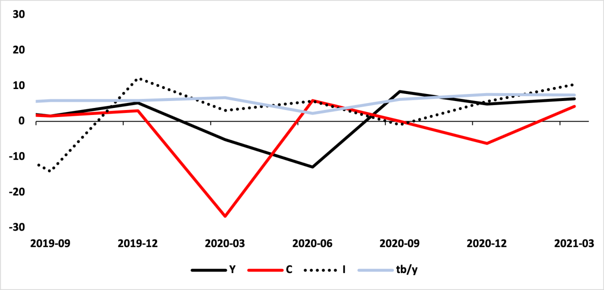


Figure 4: Business Cycles during Pandemic

Research Question

Question?

What is the main driving forces of business cycles during COVID-19?

- permanent or transitory? amplification mechanism? heterogeneous responses?

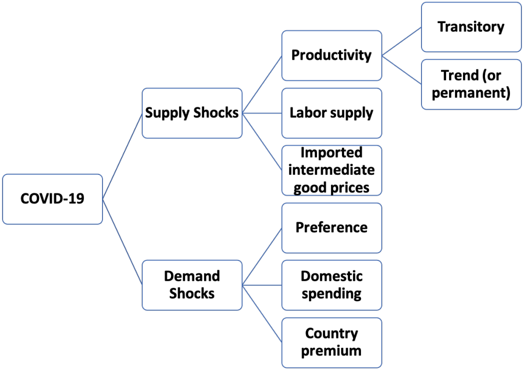


Figure 5: Structural Shocks from COVID-19

Research Objectives

This paper

- quantifies relative importance of structural shocks during the pandemic.
- explore an economic mechanism to determine which frictions amplify the shocks.
- estimate heterogeneous responses across industrial sectors.

Issues to think about

- appropriate business cycle model for the Korean economy.
- which structural shocks matter (temporary or permanent?)
- frictions for the Korean economy.
- sectoral responses to identified shocks.

Research Design

Step 1. Main Driving Sources of COVID-19 Crisis

- Small open economy model with Recursive preference and Financial-frictions.
- 7 shocks: Two productivity / Labor supply / Preference / Domestic spending / Country premium / Imported intermediate goods prices

Directions

- ... estimate the second-order solution of the model based on the *Gaussian mixture filter (GMF)* with MCMC (diffuse prior) (Noh, 2020).
- ... analyze which structural shocks matter for a small open economy.
- ... perform counterfactual analysis to find the amplification mechanism of COVID-19 shock.

Research Design

Step 2. Sectoral Responses to the Pandemic

- Structural VAR with recursive identification
- Variables of interest
  - Estimated structural shocks from DSGE model
  - Sectoral output: Manufacturing, Services, Construction, Utilities

Directions

- ... estimate SVAR with Block exogeneity using Cholesky decomposition.
- ... estimate IRFs across four industries.
- ... estimate IRFs across sub-categories of the most vulnerable industry.

Aggregated Effect of Macro Shocks

COVID-19 ≈ Supply disruptions as Productivity shocks

- Guerrieri et al. (2020), Fornaro et al. (2020), Céspedes et al. (2020)
- Wealth effect, Sectoral spillover, or Endogenous productivity

Supply shocks ⇒ Aggregate Demand ↓ ⇒ Recession

COVID-19 ≈ Supply and Demand Shocks

- Baqaee and Farhi (2020) with disaggregated model
- Supply shocks: Shrinkage of production possibility frontier
- Demand shocks: Change in composition of consumption bundles and intertemporal changes in consumption

Supply shocks ⇒ Stagflation
Demand shocks ⇒ Deflation

Heterogeneous Responses to the Pandemic

COVID-19 makes Difference

- Adam-Prassl et al. (2020), Dingel and Neiman (2020), etc...
- Heterogeneity across Countries, Industries, Types of Job, Gender, Education level, Share of work from home

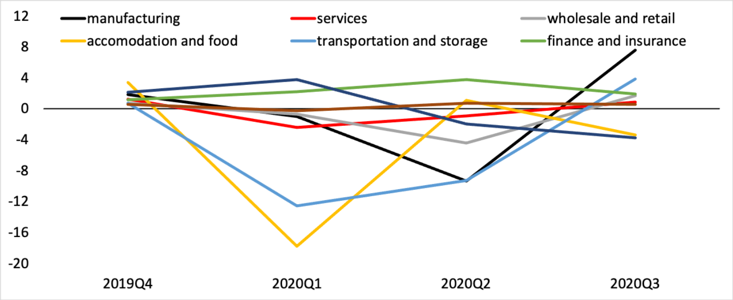


Figure 6: Sectoral growth rates during COVID-19

Models and Estimation

Model overview

- Epstein-Zin recursive preferences
- Labor market imperfection with labor supply shocks (wage markup shocks)
- Financial frictions model
- Working capital constraints
- Imported intermediate goods
- Seven structural shocks: trend and transitory productivity shocks, preference, labor supply, domestic spending, country premium, relative price of imported intermediate goods

Preferences

- Epstein-Zin preference:

$$V_t = \left\{ (1-\beta) v_t \left[C_t - \zeta_t \omega^{-1} G_{t-1} h_t^{\omega} \right]^{\frac{1-\gamma}{\theta}} + \beta \left[E_t \left(V_{t+1}^{1-\gamma} \right) \right]^{\frac{1}{\theta}} \right\}^{\frac{\theta}{1-\gamma}}, \quad (1)$$

subject to

$$\frac{D_{t+1}}{1+r_t} = D_t - Y_t + C_t + S_t + I_t + \frac{\eta r_t}{1+r_t} \left(w_t G_t h_t + q_t X_t \right) + \frac{\phi}{2} \left(\frac{K_{t+1}}{K_t} - \mu_g \right)^2 K_t, \quad (2)$$

- Trade balance:

$$TB_t = D_t - \frac{D_{t+1}}{1+r_t} = Y_t - C_t - S_t - I_t - \frac{\eta r_t}{1+r_t} \left(w_t G_t h_t + q_t X_t \right) - \frac{\phi}{2} \left(\frac{K_{t+1}}{K_t} - \mu_g \right)^2 K_t. \quad (3)$$

- $\theta = \frac{1-\gamma}{1-\frac{1}{\kappa}}$ determines preference between early and late resolution of uncertainty ($\kappa = \frac{\theta}{\theta+\gamma-1}$, elasticity of intertemporal substitution)

Technology

- Technology: $Y_t = a_t K_t^{\alpha_1} X_t^{\alpha_2} (G_t h_t)^{1-\alpha_1-\alpha_2} - q_t X_t$.
- Working capital constraints: $\kappa_t \geq \eta(w_t G_t h_t + q_t X_t)$
- Firm's problem:

$$E_0 \sum_{t=0}^{\infty} \beta^t \frac{\lambda_t}{\lambda_0} \left[a_t K_t^{\alpha_1} X_t^{\alpha_2} (G_t h_t)^{1-\alpha_1-\alpha_2} - u_t K_t - \left(1 + \frac{\eta r_t}{1+r_t}\right) [w_t G_t h_t + q_t X_t] \right], \tag{4}$$

- Country interest rate:

$$r_t = r^* + \psi \left[\exp\left(\frac{\tilde{D}_{t+1}/G_t - \bar{d}}{\bar{y}} \right) - 1 \right] + \exp(\eta_t - 1) - 1. \tag{5}$$

Firm's problem

- Technology: $Y_t = a_t K_t^{\alpha_1} X_t^{\alpha_2} (G_t h_t)^{1-\alpha_1-\alpha_2} - q_t X_t$.
- Stationary prod. shocks:

$$\log a_{t+1} = \rho_a \log a_t + \varepsilon^a_{t+1}, \tag{6}$$

  where $\varepsilon^a_{t+1} \sim iidN(0, \sigma_a^2)$.
- Nonstationary prod. shocks:

$$\log(g_{t+1}/\mu_g) = \rho_g \log(g_t/\mu_g) + \varepsilon^g_{t+1}, \tag{7}$$

  where $\varepsilon^g_{t+1} \sim iidN(0, \sigma_g^2)$.
  Let g_t be the gross growth rate of nonstationary prod. shocks G_t:

$$G_t = g_t G_{t-1}. \tag{8}$$

- Relative price of imported intermediate goods:

$$\ln(q_{t+1}/\mu_q) = \rho_q \ln(q_t/\mu_q) + \varepsilon^q_{t+1}. \tag{9}$$

Law of motion of structural shocks

- Country interest rate shocks:

$$\log\eta_{t+1} = \rho_\eta \log\eta_t + \varepsilon^{\eta}_{t+1}, \tag{10}$$

- Spending shocks:

$$\log(s_{t+1}/\mu_s) = \rho_s \log(s_t/\mu_s) + \varepsilon^{s}_{t+1} \tag{11}$$

- Preference shocks:

$$\log v_{t+1} = \rho_v \log v_t + \varepsilon^{v}_{t+1} \tag{12}$$

- Labor supply shocks:

$$\ln(\zeta_{t+1}/\mu_\zeta) = \rho_\zeta \ln(\zeta_t/\mu_\zeta) + \varepsilon^{\zeta}_{t+1} \tag{13}$$

Solution, Calibration, and Estimation

Solution

- Solve model up to second-order with pruning (Kim et al., 2008 details)

Calibration

- Calibrate parameters based on Garcia-Cicco et al., (2010) and Rhee (2017)

Estimation

- Estimate the model using the Gaussian mixture filter with MCMC (Noh, 2020 details).

Data (1900 - 2005)

- **5 observable variables:** output growth, consumption growth, investment growth, trade balance to output ratio, and relative price of imported intermediate goods

Calibration

- Calibration based on Garcia-Cicco et al., (2010) and Rhee (2017)

Table 2: Calibration

Parameter	Description	Value
δ	Depreciation rate	0.025
α_1	Capital share of income	0.35
α_2	Imported intermediate input share of income	0.124
ω	Labor supply elsasticity	1.6
μ_ζ	Labor parameter	2.24
r^*	World interest rate	0.0067
β	Discount factor	$\frac{\mu_g^{\frac{\gamma+\theta-1}{\theta}}}{1+r^*}$

Estimation Results

Financial frictions model

- Both trend and transitory productivity shocks are significant.
- Shocks to the relative price of imported intermediate goods are persistent.

Parameter	Prior Dist.	Posterior Dist.		
		Median	5%	95%
σ_g	Inv. Gamma(0.01,1)	0.004	0.002	0.007
ρ_g	Beta(0.7,0.2)	0.632	0.385	0.835
σ_a	Inv. Gamma(0.01,1)	0.005	0.003	0.006
ρ_a	Beta(0.7,0.2)	0.957	0.761	0.983
σ_ν	Inv. Gamma(0.01,1)	0.028	0.017	0.044
ρ_ν	Beta(0.7,0.2)	0.861	0.741	0.959
σ_s	Inv. Gamma(0.01,1)	0.063	0.054	0.075
ρ_s	Beta(0.7,0.2)	0.840	0.719	0.910
σ_η	Inv. Gamma(0.01,1)	0.002	0.001	0.003
ρ_η	Beta(0.7,0.2)	0.419	0.225	0.620
σ_ζ	Inv. Gamma(0.01,1)	0.006	0.002	0.014
ρ_ζ	Beta(0.7,0.2)	0.803	0.393	0.979
σ_q	Inv. Gamma(0.01,1)	0.029	0.025	0.033
ρ_q	Beta(0.7,0.2)	0.973	0.939	0.993

Table 3: Financial frictions model (1)

Financial frictions model

- small weight on the role of financial friction
- working capital constraints matter
- $\gamma(3.999) \geq \frac{1}{\kappa}(2.765)$: prefer early resolution of uncertainty

Parameter	Prior Dist.	Posterior Dist.		
		Median	5%	95%
ϕ	Uniform(0,8)	4.533	3.107	6.583
ψ	Uniform(0,10)	0.004	0.002	0.012
θ	Normal(2,0.5)	1.669	1.029	2.718
γ	Normal(5,2.5)	3.999	1.600	7.120
μ_g	Normal(1.0089,0.002)	1.000	1.000	1.001
η	Uniform(0,1)	0.306	0.024	0.866
Marginal likelihood		1070.7		

Table 4: Financial frictions model (2)

Basic Statistics

Statistics	Output Growth	Conusmption Growth	Investment Growth	Trade Balance to Output ratio
Standard deviation				
Financial-frictions model	1.272	1.725	5.326	2.350
Data	0.988	1.258	4.768	2.439
Correlation with output growth				
Financial-frictions model		0.735	0.634	-0.261
Data		0.524	0.511	-0.188
Correlation with TB/Y				
Financial-frictions model		-0.272	-0.275	
Data		-0.213	-0.220	
Serial correlation				
Financial-frictions model	0.016	-0.036	-0.161	0.756
Data	0.187	0.159	-0.069	0.786

Table 5: Comparing Model and Data: Second Moments Statistic

Variance Decompositions

Table 6: Variance Decomposition

Nonlinear	Output Growth	Conusmption Growth	Investment Growth	Trade Balance to Output ratio
Permanent prod.	0.39 (15.79)	0.39 (9.85)	2.37 (19.95)	1.56 (28.94)
Transitory prod.	0.96 (38.87)	0.94 (23.74)	2.25 (18.94)	0.58 (10.76)
Labor supply	0.35 (14.17)	0.3 (7.58)	0.42 (3.54)	0.09 (1.67)
Imported Intermediate price	0.65 (26.32)	0.67 (16.92)	1.67 (14.06)	0.54 (10.02)
Preference	0.03 (1.21)	1.1 (27.78)	0.63 (5.30)	0.58 (10.76)
Country premium	0.05 (2.02)	0.33 (8.33)	3.67 (30.89)	1.2 (22.26)
Domestic spending	0.04 (1.62)	0.23 (5.81)	0.87 (7.32)	0.84 (15.58)
All shocks	1.27	1.72	5.33	2.35

Estimated productivity shocks

details

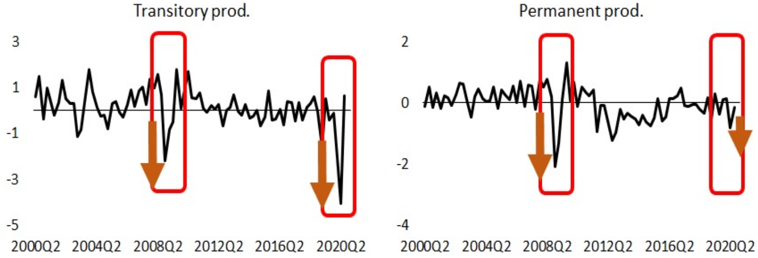


Figure 7: Estimated productivity shocks

Estimated other shocks

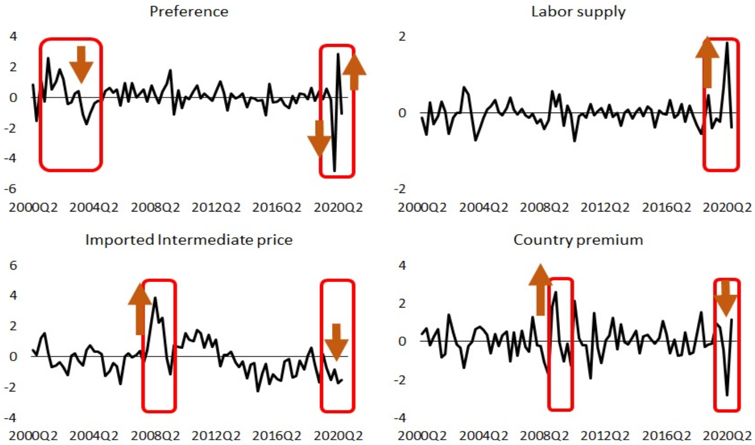


Figure 8: Estimated other shocks

Sources of Business Cycles during COVID-19

Simulating COVID-19 crisis

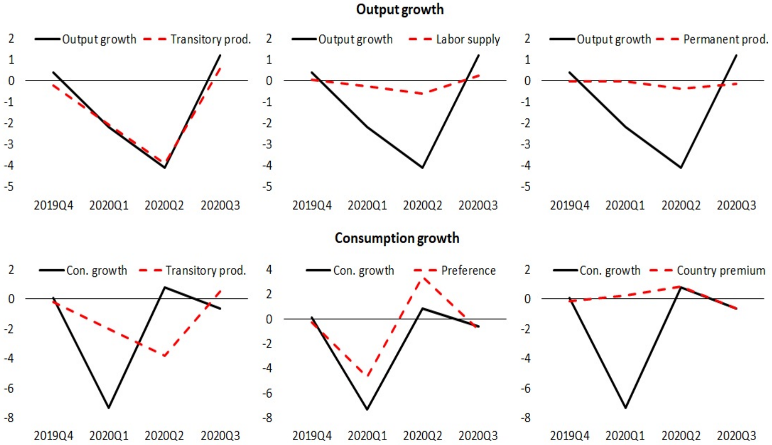


Figure 9: Shock impacts in COVID-19

Simulating COVID-19 crisis

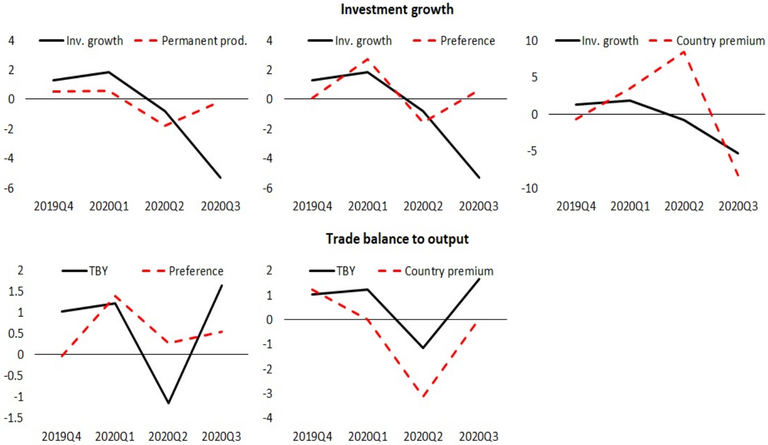


Figure 10: Shock impacts in COVID-19

Counterfactual analysis

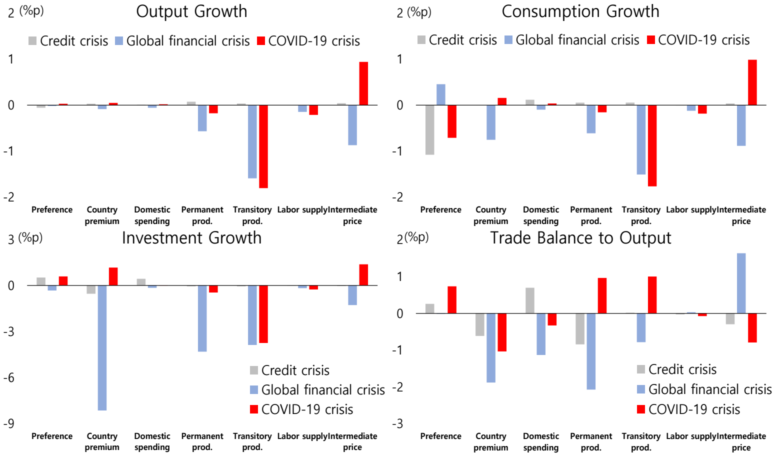


Figure 11: Shock impacts in COVID-19

Counterfactual analysis

- Capital adjustment costs, EIS, and working capital constraints matter for the amplification of the shocks.

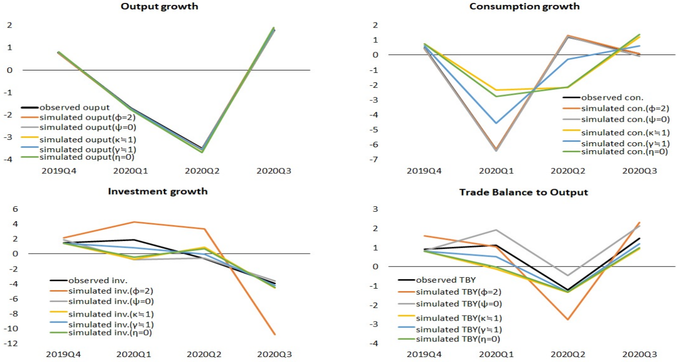


Figure 12: Model comparison during COVID-19 crisis

Heterogeneous responses: empirical VAR

- Heterogeneous sectoral output responses to model implied shocks?
- Empirical VAR Model

$$Y_t = c + \sum_{i=1}^{P_1} \phi_i Y_{t-i} + \Sigma_t^{1/2} \varepsilon_t, \quad \varepsilon_t \sim N(0,1). \tag{14}$$

- Y_t contains "structural shocks", "manufacturing", "construction", "service"
- try a group of sub-level service sector (wholesale and retail, accommodation and food, transportation and storage...)

Heterogeneous responses

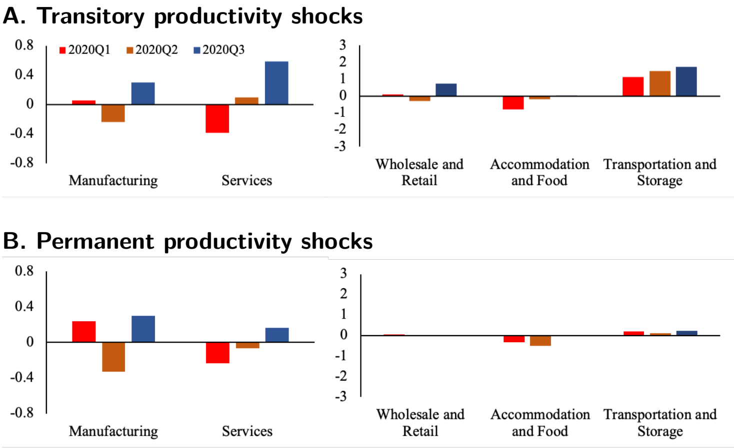


Figure 13: Heterogeneous responses (1)

Heterogeneous responses

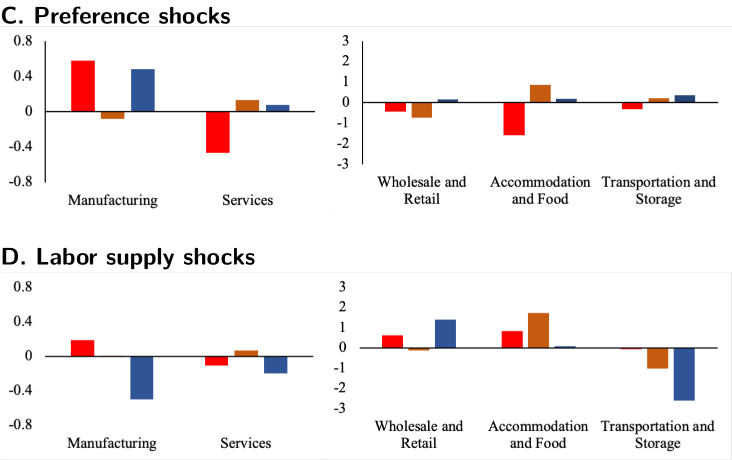


Figure 14: Heterogeneous responses (2)

Conclusion

During COVID-19, ...

1. A dominant role of transitory productivity shocks in explaining the economic downturn.
2. Preference shocks have significant impacts on consumption growth.
3. Households adjust their intratemporal preference between labor supply and consumption.
4. Capital adjustment costs, EIS, and working capital constraints matter for the amplification of the shocks.
5. Heterogeneous sectoral responses (accommodation and food mostly affected among service sector).

Second-order pruned perturbation

back

- Second-order pruned perturbation,

$$\mathbf{X_{t+1}} = \begin{bmatrix} \hat{\mathbf{x}}^f_{t+1} \\ \hat{\mathbf{x}}^s_{t+1} \end{bmatrix} = \begin{bmatrix} \mathbf{h_x}\hat{\mathbf{x}}^f_t + \sigma\boldsymbol{\eta}\boldsymbol{\epsilon}_{t+1} \\ \mathbf{h_x}\hat{\mathbf{x}}^s_t + \frac{1}{2}\mathbf{H_{xx}}\left(\hat{\mathbf{x}}^f_t \otimes \hat{\mathbf{x}}^f_t\right) + \frac{1}{2}\mathbf{h}_{\sigma\sigma}\sigma^2 \end{bmatrix} \tag{15}$$

$$\mathbf{Y_t} = \mathbf{g_x}(\hat{\mathbf{x}}^f_t + \hat{\mathbf{x}}^s_t) + \frac{1}{2}\mathbf{G_{xx}}(\hat{\mathbf{x}}^f_t \otimes \hat{\mathbf{x}}^f_t)) + \frac{1}{2}\mathbf{g}_{\sigma\sigma}\sigma^2 \tag{16}$$

where we eliminate the terms of higher-order effects by using a pruning method (see, in particular Kim et al. (2008); Andreasen et al. (2017)).

Bayesian Estimation for Nonlinear Solution

back

- Difficult problem of sampling from $p(\theta, x_{1:T}|y_{1:T})$ is reduced to that of sampling from

$$p(\theta|y_{1:T}) \propto p(y_{1:T}|\theta)p(\theta) \tag{17}$$

- However,
  - The posterior distribution does not have a closed form expression.
  - The marginal likelihood function can not be evaluated in closed-form in a non-linear state space representation.
- We use pseudo-marginal Metropolis-Hastings (PM-MH) algorithm based on the following acceptance probability

$$\hat{\alpha}(\theta^*|\theta_{i-1}) = min\{1, \frac{\hat{p}(y_{1:T}|\theta^*)p(\theta^*)q(\theta_{i-1}|\theta^*)}{\hat{p}(y_{1:T}|\theta_{i-1})p(\theta_{i-1})q(\theta^*|\theta_{i-1})}\} \tag{18}$$

- **KEY:** is to evaluate the pseudo-marginal likelihood, $\hat{p}(y_{1:T}|\theta)$ that is close to the true marginal likelihood.

Likelihood evaluation: Gaussian mixture filter back

- It is based on the fact that any distribution can be obtained by mixing Gaussian distributions (Alspach and Sorenson 1972).
  1. prediction density

$$p(x_k|y_{1:k-1};\theta) \approx \sum_{l'=1}^{L'} w_k^{[l']} N(x, \tilde{\mu}_k^{[l']}, \tilde{P}_k^{[l']}) = \sum_{l'=1}^{L'} w_k^{[l']} p_{l'}(x_t|y_{1:t-1};\theta) \quad (19)$$

  2. filtering density

$$p(x_k|y_{1:k};\theta) \approx \sum_{l''=1}^{L''} w_t^{[l'']} N(x_t;\mu_t^{[l'']}, P_t^{[l'']}) = \sum_{l''=1}^{L''} w_k^{[l'']} p_{l''}(x_t|y_{1:t};\theta) \quad (20)$$

- Mixture component is updated by the Central Difference Kalman filter.

$$\begin{aligned} \hat{p}^{\text{GMF}}(y_t|y_{1:t-1};\theta) &= \int p(y_t|x_t;\theta)p(x_t|y_{1:t-1};\theta)dx_t \\ &= \sum_{l'=1}^{L'} \sum_{n=1}^{N} w_t^{[l']} \gamma_t^{[n]} N(\hat{y}_{t|t-1}^{[l' \times n]}, P_{t|t-1}^{y,[l' \times n]}) \end{aligned} \quad (21)$$

Likelihood evaluation: Gaussian mixture filter

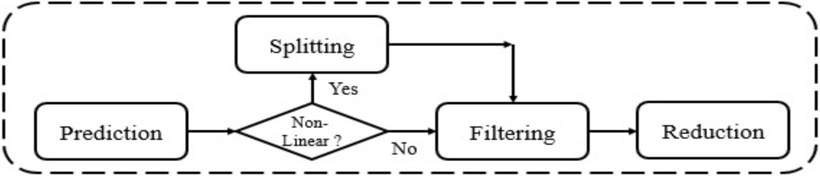
back

- **Splitting** procedure for each mixture component $(p_{l'}(x_t|y_{1:t-1};\theta),\ p_{l''}(x_t|y_{1:t};\theta))$ based on Binomial Gaussian mixture (Raitoharju, Ali-Löytty, and Piché, 2015).

  details

  - When the measure of nonlinearity is above a pre-specified threshold (η_{limit}), I implement the splitting.
  - Splitting is performed in a direction where the high nonlinearity occurs.
  - The number of mixture components are restricted to the point where the size of nonlinearity is below the threshold.
- **Reduction** procedure based on Kullback-Leibler (KL) discrimination following Runnalls (2007).

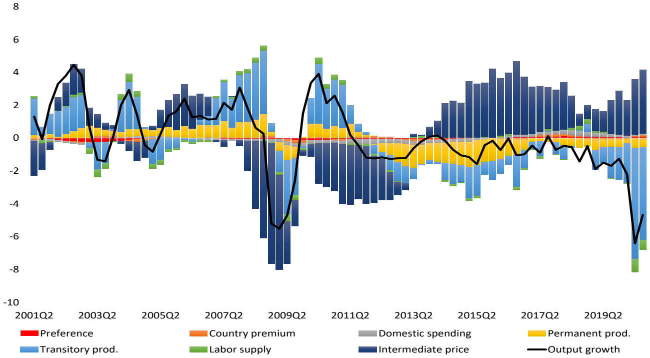
Figure 15: Flow Chart



Historical decomposition

back

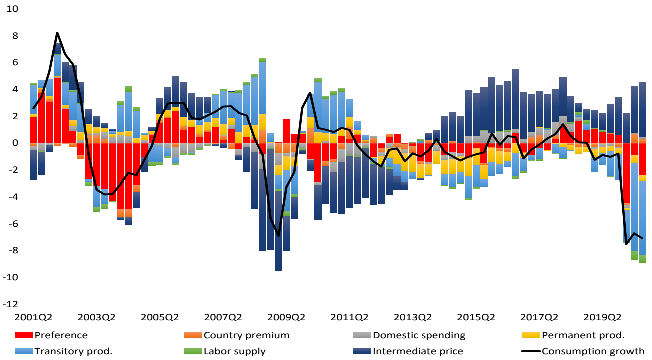
Figure 16: Historical decomposition: output growth



Historical decomposition

back

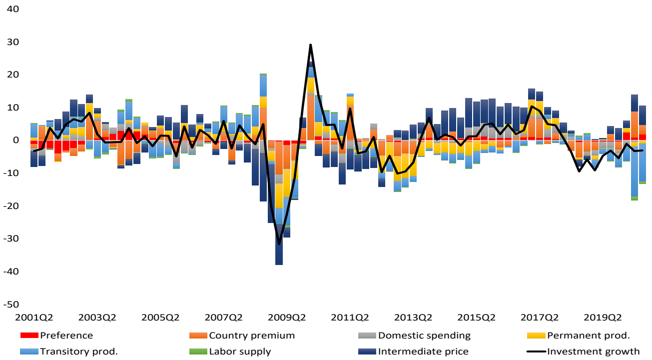
Figure 17: Historical decomposition: consumption growth



Historical decomposition

back

Figure 18: Historical decomposition: investment growth



Historical decomposition

back

Figure 19: Historical decomposition: trade balance to output