Inequality of Fear and Self-Quarantine: Is There a Trade-off Between GDP and Public Health?

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Our Contributions

1. Infections and deaths growing out of control is bad for the economy:
    - **Fear of Infection, aka "Fear Factor"**
    - Important in theory but less prominent in quantitative work
2. Based on real-world, not "optimal" policies: SK vs UK:
    - **Targeted quarantine from testing** vs **blanket lock-down**
    - **making sure you stay home** vs **sending you home**
3. Predictions on **inequality** as well as GDP:
    - Low-wage workers more exposed to virus
    - Also more exposed to job/wage losses

Main Results

1. From January-October 2020,
   - SK's test/trace/tracking (TTT) policy contains virus with **1.2% GDP loss with 837 cumulative deaths**
   - UK's lockdown partly contains virus with **11% GDP loss with 65253 cumulative deaths**

   ⇒ Demographics and economic structure make little difference

2. **SK:** quarantine enforcement more important than asymptomatic testing

3. **UK:**

early lockdown:	50% less deaths,	1.2% point extra loss in GDP
extended lockdown:	25% less deaths,	2.0% point extra loss in GDP

   from Jan to Oct 2020

4. Low-skill workers and self-employed bear brunt of crisis
   - Higher infection risk at work + larger fear of infection
   - Lower productivity when WFH

Overview

1. Model — **Fear of Infection and Self-Quarantines**
2. Policy Tools — **Test/Trace/Track/Lockdown**
3. Calibration — **Economics, Epidemiology and Policies**
4. Results — **Infections, GDP and Inequality**
5. Counterfactual Analysis — **Early and Long Lockdowns**

A. Testing and Quarantine Enforcement

Model

Environment

- No capital, **labor-only economy**
  1. **{Young vs Old}**: latter don't work
  2. **{High vs Low}** skill, perfectly segregated labor market

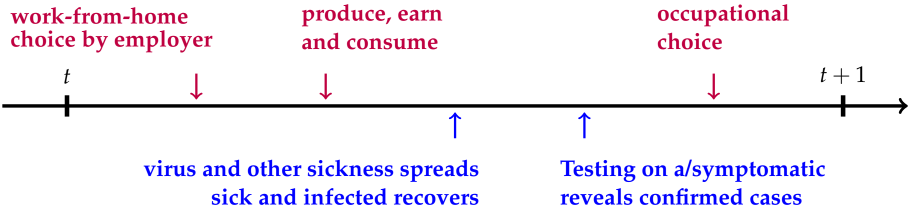
     indexed by $x \in \{h, l\}$
  3. Occupation choice: **{self-employed, manager, worker}**

     indexed by $j \in \{1, 2, 3\}$

- Infection status evolves by $i \in \{(x, j), o, q\}$: quarantined
  1. Unobserved, true status: $E_i \in \{S, I, R, D\}$
  2. Observed status: a/sympomatic×un/tested/recovered

     $e_i \in \{a^0, s^0, a^c, s^c, a^r, s^r, d = D\}$

Timeline (Daily)



- Economic model (in red) only applies to young

Observed Status

- **Sick**: has Covid-like symptoms (a/symptomatic)
  1. may or may not have Covid
  2. can have symptoms regardless of (S, I, R)

- **Testing**: only positive for infected I
  1. infection status may or may not be detected
  2. differential testing of a/sympotmatic (τ_a, τ_s)
  3. Covid cannot be detected after recovery

  $\Rightarrow$ Recovery only confirmed if tested positive during infection

True, Unobserved Infection Status: SIR Model

- Unmitigated mass of infections:

$$I^* = I - QI_q, \quad \mathbf{0} \leq Q \leq \mathbf{1}$$

Q: intensity of quarantines, I_q: how many people quarantine

- Bare-bones SIR model, but exposure to virus heterogeneous by i

$$v_i(I^*) = \bar{v}_i \cdot I^* / N, \quad N : \text{population size}$$

- **Fear factor**: zero if *confirmed* recovered, otherwise

$$\chi_i(I^*, e) = \bar{\chi} \cdot v_i(I^*)$$

$\Rightarrow$ $\chi_i(I^*, e)$: differs by $i \in \{(x, j)\}$, but equal if at home $i = q$

Work-from-home Choice

1. Logit discrete choice between {commuting, self-quarantine}

2. Heterogeneity:
   - $r_{x,j}$: returns for skill x, occupation j
   - $\psi_{x,j}$: productivity discount from working from home
   - $\chi_{x,j}$: fear factor depends on job and whether quarantined or not
   - $\bar{\rho}_{x,j}$ lockdown intensity by ind/occ (Palomino et al., 2020)

3. Government can isolate symptomatic and/or confirmed positive

Closing the model

1. Fraction $\nu = 1/365$ of workers get chance to switch occupation

2. Second EV shock for occupational discrete choice

3. Log-preferences and Cobb-Douglas high-skill share θ

4. Markets clear daily

* More assumptions eliminate fixed-points for fast computation

Policy Tools

Test/Trace/Track, Lockdown

1. τ_a, τ_s: Testing & Tracing, testing asymptomatic is tracing
2. Q: "Tracking" is quarantine-enforcement
3. $\rho_{x,j}(e)$: Lockdown intensity on impact
4. Fit UK lockdown with time-varying sigmoid function

$$\varphi(t; t_\lambda, T_\lambda, \lambda) = \max\left(0, \min\left\{\left[1 + \left(\frac{t - t_\lambda}{T_\lambda - t}\right)^{\lambda}\right]^{-1}, 1\right\}\right)$$

- (t_λ, T_λ): start and end dates
- low λ: gradual decay
- high λ: no decay till mid-point, zero afterward

Calibration

Exogenous Parameters

- Economy: pre-pandemic steady state
  1. Demographics calibrated to census
  2. Economic parameters calibrated to SK EAPS / UK APS employment
  3. EV shocks chosen to match data employment shares in steady state

- Epidemiology:
  1. Timing assumption: Patient 0 arrives on December 22
  2. Death rates to each country's CFR
  3. Sickness and testing technologies to available data

- Heterogeneity:

$\psi_{x,j}$: **Home productivity** from ACS and ATUS 2014-2018

$\bar{v}_i$: **Exposure** from O*NET and ACS 2014-2018

$\bar{\rho}_{x,j}$: **Lockdown GDP drop** in UK March/April

economic params | epidemiological | policy params

Targeted Parameters

1. Equal across countries:
   - $\bar{v}$: Average exposure
   - $\bar{\chi}$: SK peak GDP drop (in May) due to fear

2. True path in the model is outcome of SIR and policies
   Observed path is outcome of testing

$\Rightarrow$ Choose $(\bar{v}, \bar{\chi})$ and policies jointly so observed path matches reported path of infections in SK and UK

- Big departure from the literature
- Match data, and unreported infections considered

economic params | epidemiological | policy params

Policy Differences

- **UK lockdown:** time-varying sigmoid function

- **SK's quarantine:** intensity Q also piecewise sigmoid to match tightening and easing of restrictions

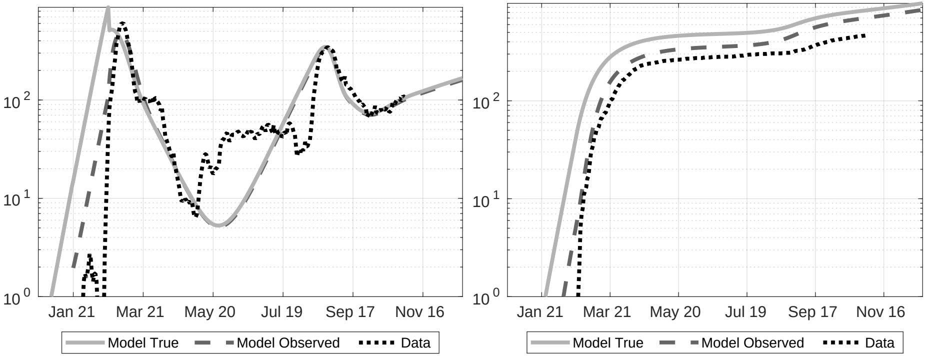
- High τ_a for SK, but 0 for UK

* *Neither UK's 2nd lockdown(s) nor SK's third wave considered (data and policies only up to 30 Oct 2020)*

▸ economic params ▸ epidemiological ▸ policy params

Results

South Korea: Results

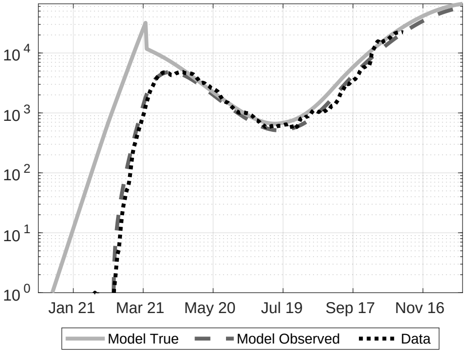


(a) SIR (b) Deaths

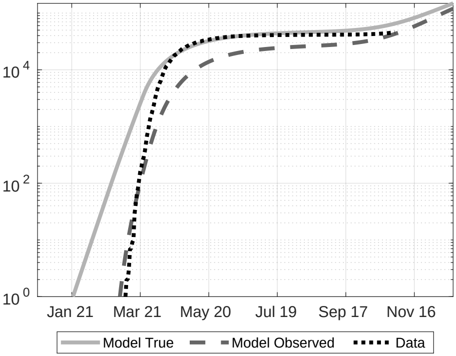
- Daily new infections and cumulative deaths in log-10 scale

Source: Korea Center for Disease Control and Prevention

United Kingdom: Results



(a) SIR

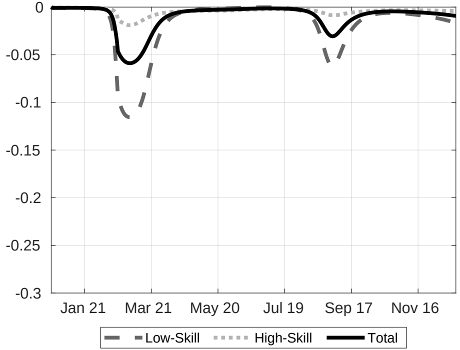


(b) Deaths

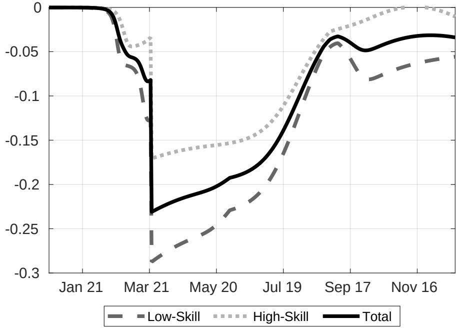
- Daily new infections and cumulative deaths in log-10 scale

Source: UK Department of Health and Social Care: delayed reports...

GDP Losses and Inequality



(a) SK



(b) UK

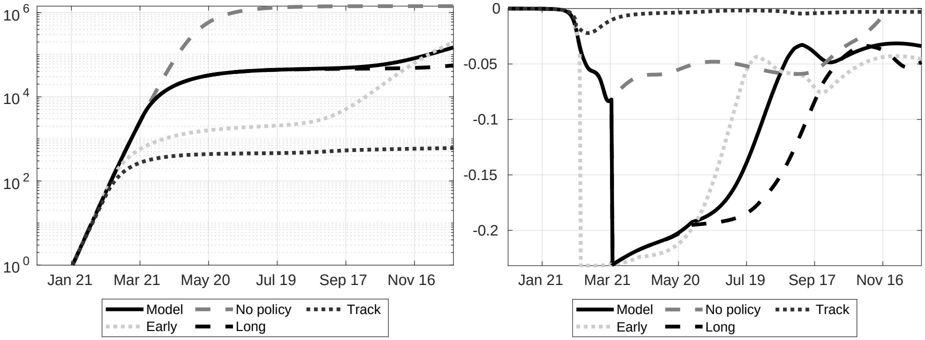
- SK peak drop similar in magnitude (but with delay)
- UK path comparable to data, both before and after lockdown
- **Aggregate GDP losses predominantly from low-skill**

Counterfactual Analysis

What Did Policies Do?

1. How important were UK lockdown and SK TTT?
2. What if UK did SK policy, and vice versa?
3. UK: Was lockdown too late or lifted too early?
4. SK: Was it testing, or self-quarantines?

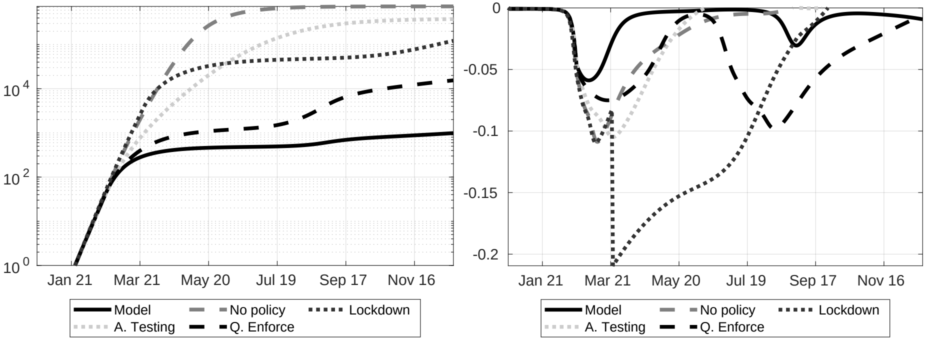
UK Counterfactuals



(a) SIR (b) GDP

1. Lockdown ''flattens'' both infection **and GDP curve**
2. **TTT policy** lowers infection and GDP loss by order of magnitude
3. Early and long lockdown reduces deaths at minimal cost to GDP

SK Counterfactuals



(a) SIR (b) GDP

- SK and UK outcomes different due to differences in policy& behavior, not economic or demographic environment
- Asympotmatic testing alone less effective
- Enforcement effective even without aggressive testing

Policy Effects: Summary

UK	**Lockdown**	No policy	Track	Early	Long
Deaths	65,253	1,424,800	573	31,402	47,501
GDP	-11.0	-4.8	-0.5	-12.2	-13.0
SK	**Track**	No policy	Lockdown	A. Testing	Q. Enforce
Deaths	837	729,641	65,403	356,228	10,933
GDP	-1.2	-2.0	-8.4	-2.2	-4.7

- Cum. deaths and average GDP loss from 1 Jan to 30 Oct, 2020
- GDP loss in log-point deviations from 2019 average

Conclusion

Main Takeaways

1. GDP and COVID containment not necessarily trade-off
   - **Fear Factor** reduces economic activity
   - **Certain NPI's can reduce both infections and GDP cost**

2. Template for analyzing different types of policies

   quarantine **intensity** vs **extensive** lockdowns

3. Template for simulating **distributional outcomes** in conjunction with aggregate outcomes
   - Low-skill more exposed to virus **and** adverse economic outcomes
   - Easy to model subsidies for SE and employer-backed furloughs

* In progress:
   - SK with fiscal policies (✓)
   - UK with fiscal policies + extra demographics and finer economic structure

Thank You
Happy New Year!

Parameter	Value		Description
	South Korea	United Kingdom	
L_y	1	1	Mass of young
L_o	0.2432	0.3711	Mass of old
$L^0_{l,j}$	[0.0810, 0.0420, 0.3268]	[0.0654, 0.0641, 0.4484]	Initial employment share
$L^0_{h,j}$	[0.0543, 0.0322, 0.4637]	[0.0584, 0.0444, 0.3192]	by industry/occupation
$\psi^0_{l,j}$	[0.6836, 0.6675, 0.6433]	[0.6780, 0.6721, 0.6427]	Home productivity discounts
$\psi^0_{h,j}$	[0.7687, 0.7801, 0.7605]	[0.7723, 0.7798, 0.7648]	by industry/occupation
$\phi^0_{l,j}$	[0.4850, 0.5711, 0.5207]	[0.6532, 0.6710, 0.5986]	Sick productivity discounts
$\phi^0_{h,j}$	[0.5819, 0.9967, 0.8722]	[0.9368, 0.9975, 0.8976]	by industry/occupation
$z_{l,j}$	[1.2586, 1.0 1.0]	[1.0529, 1.0, 1.0]	Effective productivities
$z_{h,j}$	[2.0566, 1.3, 1.3]	[1.3117, 1.3, 1.3]	by industry/occupation
κ	0.0861	0.0884	Sickness disutility
α_l, α_h	[0.2996, 0.1747]	[0.2406, 0.2133]	Manager wage share by industry
θ	0.4133	0.5172	l-skill wage share in final good prod
σ	0.0323	0.0345	Scale parameter, EV distribution for home-work choice
$\mu_{l,j}$	[0, -0.6467, 1.7461]	[0, -0.0141, 2.1442]	Location parameter, EV distribution
$\mu_{h,j}$	[0, -0.5137, 2.5460]	[0, -0.2657, 1.9116]	for occupation choice
ν	1/365		Can switch occupation once a year

Exogenous Targeted Policy

Parameter	Value	Description
δ_y	0	Young daily natural death rate
δ_o	5.48e-05	Old annual natural death rate of 2 percent
γ_y	1/14	Young recover in 2 weeks
γ_o	$\gamma_y/2$	Old recover in 4 weeks
m_o	[0.0042,0.0054]	Age 65+ CFR of [11.8,15.2] in SK,UK as of 30 Oct 2020
m_y	$=m_o/30$	Age 15-65 CFR of [0.4,0.5] in SK,UK as of 30 Oct 2020
$v_{l,j}$	[0.3174, 0.0838, 0.4383]	Exposure index in Aum et al. (2020)
$v_{h,j}$	[0.1456, 0.0000, 0.2118]	for SK employment structure
$v_{l,j}$	[0.3083, 0.0570, 0.3644]	for UK employment sturcture
$v_{h,j}$	[0.1397, 0.0000, 0.2606]	(normalized to have mean v_o and $v_{h,1} = 0$)
v_q	$=v_o/7$	Reduce social contact to 1 day a week in quarantine
v_o	0.2786	Old infection rate to match $R_0 = 3.9$
I_0	[2.6, 2.3]×1e-08	1 person infected on Dec 22nd ($t = 0$)
$\bar{\chi}$	5000	Fear factor: 6 percent GDP drop in SK at peak infection
ω	0.8	20 percent false negatives (Yang et al., 2020)
$f_y = f_o$	0.03	Sick without COVID: annual respiratory illnesses
(η_y, η_o)	[0.3,0.6]	Young and old infected with symptoms (Davies et al., 2020)
$\rho_{l,j}$	[0.7463, 0.7101, 0.6891]	Fraction locked down from Palomino et al. (2020)
$\rho_{h,j}$	[0.9014, 0.8179, 0.7992]	for SK employment structure (only for counterfactuals)
$\rho_{l,j}$	[0.7370, 0.7456, 0.7303]	for UK employment structure
$\rho_{h,j}$	[0.9598, 0.8135, 0.7818]	

Parameter	Value	Description
λ	4	UK lockdown: [April,August] year-on-year GDP drop [-24,-10]%
t_λ, T_λ	[92,362]	UK lockdown: start and end dates
(τ_a, τ_s)	[timeline below]	Test rates for a/symptomatic
$Q = \bar{Q}$	[timeline below]	Tracking policy

Country	Date	Event	Testing	Quarantines
SK	Dec 22, $t = 0$	No detection	$(\tau_a, \tau_s) = 0$	$Q = 0$, no quarantines
	Jan 20, $t = 29 = \tau$	First detection	$(\tau_a, \tau_s) = (0, 0.03)$	$Q = 0.1$
	Feb 20, $t = 60$	Shincheonji outbreak	$(\tau_a, \tau_s) = \tau_1$	$Q = q_1$
	Apr 18, $t = 116$	Social restrictions eased	$(\tau_a, \tau_s) = 0.8$	$Q = q_2 + (q_1 - q_2) \cdot \varphi_2$
	Aug 15, $t = 235 = \tau$	New restrictions on Seoul	$(\tau_a, \tau_s) = 0.8$	$Q = q_3 + (q_2 - q_3) \cdot \varphi_3$
	Sep 13, $t = 264$	Seoul restrictions eased	$(\tau_a, \tau_s) = 0.8$	$Q = q_4 + (q_3 - q_4) \cdot \varphi_4$
			$\tau_1 = 0.03 + 0.77 \cdot \frac{t-59}{116-59}$	$q_1 = 0.94$ $q_2 = 0.61$, $\varphi_2 = \varphi(116, 235, 3)$ $q_3 = 0.90$, $\varphi_3 = \varphi(235, 265, 2)$ $q_4 = 0.78$, $\varphi_4 = \varphi(265, 323, 2)$
UK	Dec 22, $t = 0$	No detection	$(\tau_a, \tau_s) = 0$	$Q = 0$, no quarantines
	Feb 1, $t = 41 = \tau$	First detection	$(\tau_a, \tau_s) = (0, 0.0001)$	$Q = 0$, no quarantines
	Feb 10, $t = 50$	First quarantine	$(\tau_a, \tau_s) = (0, 0.0001)$	$Q = 0$
	Feb 24, $t = 64$	Testing system commences	$(\tau_a, \tau_s) = (0, \tau_1)$	$Q = 0.0$
	Mar 23, $t = 92 = t_\lambda$	Lockdown	$(\tau_a, \tau_s) = (0, \tau_2)$	$Q = 0.55$
	May 30, $t = 160$	Test/Tracing complete	$(\tau_a, \tau_s) = (0, 0.3)$	$Q = 0.55$
			$\tau_1 = 0.0001 + 0.0299 \cdot \frac{t-63}{91-63}$ $\tau_2 = 0.03 + 0.27 \cdot \frac{t-91}{160-91}$	

▸ Exogenous ▸ Targeted ▸ Policy

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