Economic and epidemic implications of virus containment policies: insights from agent-based simulations

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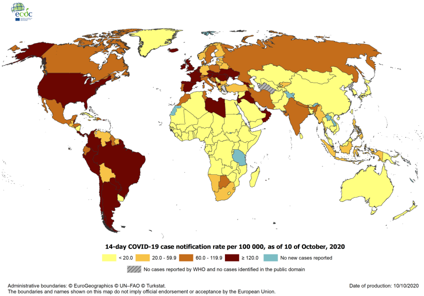
Motivation



- COVID-19 pandemic caused a global health and economic crisis: > 60 Mio. infected, > 1.4 Mio. deaths, $\approx 20\%$ loss in production (UNIDO))
- Substantial variance across countries wrt containment measures
- Substantial variance across countries wrt number of infected, casualties and also wrt economic losses
- Perceived trade-off between rapid virus containment and economic costs

Research Questions

- What are the epidemic and economic implications of different types of lock-down-policies?
  - Intensity of the lock-down
  - Degree of opening-up after lock-down
  - Time of (re-)start of the lock-down
- For which aspects of the lock-down policy does a trade-off between virus mortality and economic loss arise?
- What is the role of complementary economic support policies?

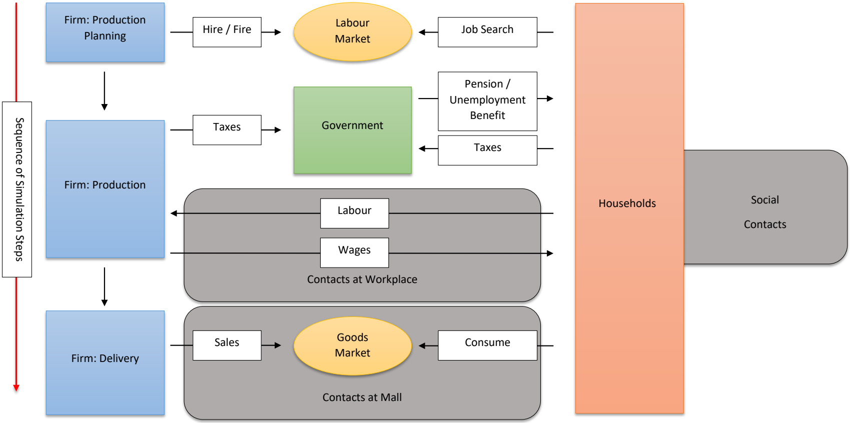
Our Approach

- Incorporate standard model of virus transmission (SIRD) into an agent-based macroeconomic framework
- Explicitly capture how interactions related to economic activity (production, consumption) act as virus transmission channels
- Calibrate based on German micro and macro data
- Systematically vary key parameters of the lock-down policy
- Analyze effect on expected virus mortality and GDP loss
- Identify 'efficiency frontier'

The model: main ingredients economics

- Households (HH)
  - Young: employed/unemployed, sector specific skills
  - Old: retired, receive pension
- Firms in 4 economic sectors: manufacturing (M), service (S), food (F), public (P)
  - Labor is only production factor (no capital goods)
  - Heterogeneity of labor productivity across firms with sector specific mean
  - Price competition (with limited information and noise) in each sector
- Behavioral rules of firms (pricing, quantity, labor demand) and households (saving/consumption, consumption choice) based on those developed in the Eurace@Unibi model (empirical micro foundations)
- Wages homogeneous in each sector

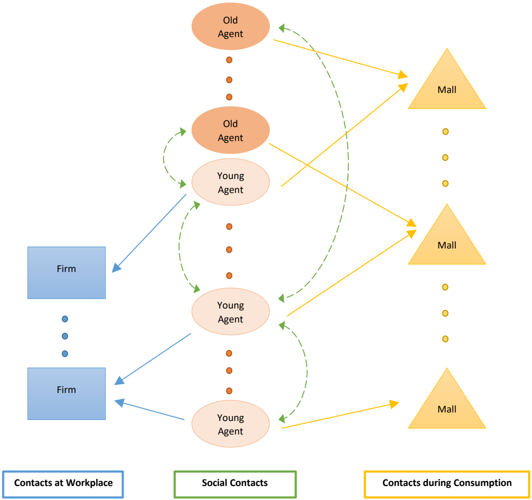
Model Overview



The model: main ingredients epidemics

- 4 potential health states for each HH
  - **S**usceptible
  - **I**nfected
  - **R**ecovered
  - **D**ead
- At each meeting between an infectious and a susceptible HH, the susceptible becomes infected with probability p_{inf}.
- Infected household recovers after t_{rec} days
- Case-specific fatality rate depends on the current utilization of available intensive care unit beds.

Transmission Channels



Policy Measures

i.) Individual prevention measures (IPM): $p_{inf} \rightarrow (1-\xi)p_{inf}$

ii.) Social distancing (SD): reduction in number of social contacts

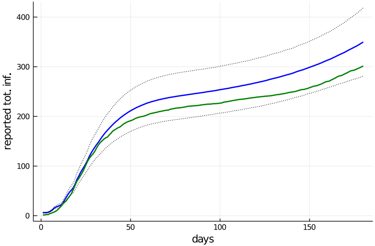
iii.) Working from home (WFH): sector specific fraction of employees have no contacts at workplace

iv.) Reduction in consumption activity (CONS): weekly shopping probability of each HH reduced from 1 to p^s

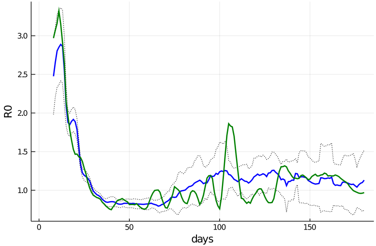
v.) Economic support (ECON):
   - short-time work: workers move to short-time work rather being laid-off, financed by public transfers
   - bailout: negative firm savings are balanced by public transfer

- i.) - iii.) have no direct negative economic effects
- Focus here is on iv.) !

Reproducing German Dynamics: March - September



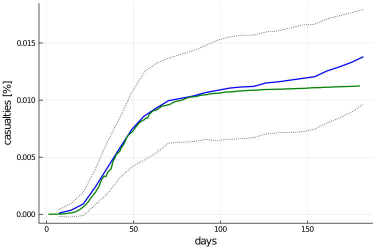
Reported total infected

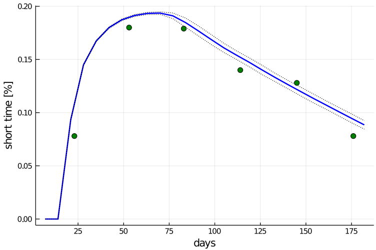


Smoothed R_0 value

Blue: (average) simulation data, Green: German data

Reproducing German Dynamics: March - September





Casualties

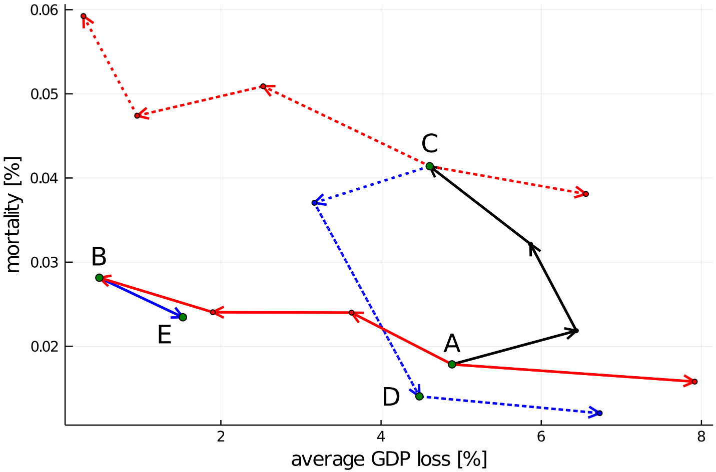
Worker in short-time work

Blue: (average) simulation data, Green: German data

Lock-down Policy

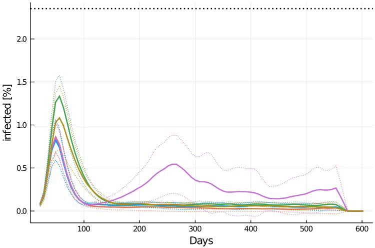
- Social distancing (SD) and reduction in consumption activity (CONS) during the lock-down
- Three key policy parameters
  - α^l: intensity of lock-down
    - $p^l = (1,1,1) - \alpha^l(0.15, 0.5, 0)$
  - α^{ol}: duration of opening
    - lock-down is re-started if reported number of newly infected in one week per 100K HHs is above α^{ol}
  - α^o: restrictions during opening-up phase
    - $p^o = (1,1,1) - \alpha^o(0.15, 0.5, 0)$
  - Default policy: $(\alpha^l, \alpha^{ol}, \alpha^o) = (1, 5, 0)$
- After 18 months $p_{inf} \to 0$ and all restrictions are lifted
- Consider total fraction of virus casualties and average weekly GDP reduction over time-horizon of 24 months

Effects of Variations of the Key Policy Parameters

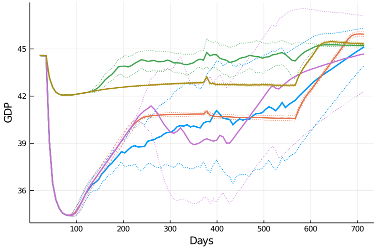


Red: α^l, Black: α^{ol}, Blue: α^o

Dynamics



Total infected



GDP (per capita)

Blue: benchmark (A: $(1, 5, 0)$), Green: weak lock-down (B: $(0.25, 5, 0)$), Purple: late lock-down (C: $(1, 50, 0)$), Red: weak opening (D: $(1, 50, 0.5)$),
Brown: weak lock-down + opening (E: $(0.25, 5, 0.25)$)

Differences wrt expected policy effects and uncertainty

	A	B	C	D	E
$(\alpha^l, \beta, \alpha^o)$	$(1, 5, 0)$	$(\mathbf{0.25}, 5, 0)$	$(1, \mathbf{50}, 0)$	$(1, \mathbf{50}, \mathbf{0.5})$	$(\mathbf{0.25}, 5, \mathbf{0.25})$
	benchmark policy	*weak lock-down*	*late lock-down*	*weak opening*	*weak lock-down+opening*
GDP loss [%]	4.88 (1.66)	0.48 (0.17)	4.61 (1.41)	4.48 (0.04)	1.53 (0.05)
Mortality [%]	0.018 (0.001)	0.028 (0.00)	0.041 (0.01)	0.014 (0.01)	0.024 (0.01)
Duration in Lock-down	124.6 (53.19)	258.65 (120.74)	114.1 (56.55)	58.1 (9.11)	159.95 (28.03)
Switch Opening/Lock-down	7.15 (3.05)	8.1 (2.67)	2.0 (0.32)	1.0 (0.0)	5.5 (2.76)
Pub. Acc. Deficit [%]	3.03 (1.01)	1.02 (0.13)	3.33 (1.61)	2.45 (0.27)	1.25 (0.10)

Conclusions

- Agent-based macroeconomic model explicitly incorporating interactions giving rise to SARS-CoV-2 transmission channels
- Calibrated model reproduces well German pandemic and economic dynamics after the outbreak of the COVID-19 crises
- Main conclusions from the policy analysis:
  - Policies with long-lasting ‘weak lockdown’ or ‘weak opening’ after initial lockdown dominate policies with switches between strong lock-down and full opening.
  - For given intensity of lockdown, a low incidence threshold for going back into lockdown should be chosen (substantially lower than incidence of 50)
  - Choice of intensity of lock-down gives rise to trade-off between mortality and GDP loss
  - Short-time work and bailout policies are very efficient in reducing both GDP loss and public deficit

Thank you for your attention!

The code of the model is available on GitHub:
`https://github.com/ETACE/ace_covid19`