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〔SUMMARY〕

Network Exposure in the Propagation of the COVID-19 Pandemic

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When COVID-19 started spreading outside of China in the end of February 2020, countries around the world decided to react differently to the spreading of the virus. While some countries, such as Germany, imposed strict precautions, trying to keep infection numbers as low as possible, others appealed to individual responsibility. Sweden even became famous for its unique "Swedish way," choosing to let the pandemic surge, only protecting vulnerable groups. Meanwhile in the US, President Trump decided to take no measures when the first wave swept across the country. Comparing the development of infection numbers per 100,000 inhabitants, the two countries show quite different patterns. Despite presumably low levels of measures in the two countries, Sweden's infections stabilized pretty quickly and came down to low levels in summer. The US, on the other hand, experienced three waves of rising incidence until winter. Another observation is that some countries have to rely on more drastic measures than others to get similar epidemic outcomes. An econ-epidemiological model needs to account for different propagation patterns, given the observed heterogeneity in stabilization of the pandemic.

Infection dynamics seem to be strongly influenced by government action as well as endogenous behaviour of the susceptible population. Therefore, we set up a microeconomic model, such as in Toxvaerd (2020) and Collard et al. (2020). The main idea is that a part of the usually exogenous coefficients in a classic SIR-type model is endogenized. In contrast to available exposure models, individuals do not only take into account the infection probability but also the exposure of other individuals (e.g., in common social activities) when choosing their individual exposure. In a first static optimization framework, individuals endogenously choose their level of exposure. We then introduce network effects into the optimization, such that individuals derive more utility from exposure if others expose themselves, too. The network-effect generates multiple equilibria. Though, the empirical relevance of these equilibria remains to be shown, the equilibrium mechanics might explain some of the patterns we see in the data. This could provide a role for the government to coordinate the individuals in order to address the externality. If the government rules out one equilibrium, individuals re-optimize. As a result of the government's role to coordinate the equilibrium as well as to contain exposure across equilibria, the marginal effectiveness of stricter measures is high in high-exposure equilibria (due to both the coordination and the containment effect), whereas stricter measures do not accomplish as much if the population has already coordinated on a low exposure equilibrium.

After showing that multiple exposure equilibria exist and that the government can coordinate between them, we move from the static optimization framework to a dynamic optimization framework. We use a discrete-time version of the model presented in Toxvaerd (2020), augmented by network-effects. In this dynamic framework agents maximize their utility, implicitly choosing their exposure by deciding over the infection probability as their relevant state variable. This structure allows us to derive an exposure-path that can be somewhat indeterminate. This indeterminacy calls for central coordination.

In our macroeconomic model, we introduce a planner taking all the previously introduced endogeneities into account. The planner maximizes utility from consumption and thus production. On the one hand production increases with higher economic activity, while higher infection levels lower production due to sick leave. In equilibrium our social planner chooses socially optimal exposure, which can be translated into reproduction numbers. Our socially optimal reproduction comes out significantly below one favoring an eradication strategy.

The final task of our paper is a proof of concept using empirical data. We show that in our data-set of European regions (ECDC, 2021), regions display endogeneity between exposure and infection levels, with reproduction numbers dropping below one at some point. Unfortunately, we cannot clearly separate governmental and private action from each other. Though the accounting identities introduced together with the epidemiological model provide some starting point, it is difficult to trace out exogenous drivers of infection probabilities. One possibility mentioned in the literature could be the usage of weather-data, what will be tried in the future.

References

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