Economic Epidemiology

Lev Paciorkowski

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Dr. Javier Espinosa

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Abstract

Economic epidemiology is a fascinating area of study that has seen rapid growth of new research in the last fourteen months as the COVID-19 SARS-2 pandemic continues to progress. This paper provides a thorough review of economic epidemiology as it has evolved over the last century and offers some insights on possible directions for future research. The organization is as follows: Section 1 is an introduction to the field, covering a brief history of economic epidemiology, its key themes and the value of studying it. Section 2 explores in greater depth the existing research, covering the most important topics under discussion. Finally, Section 3 highlights areas for future research by discussing elements of the field that are relatively understudied along with possible tweaks that could be made to existing models.

1. Introduction

Economic epidemiology takes established mathematical models used to describe disease outbreaks and infuses them with rational decision makers, often with the ultimate aim of assessing the effectiveness of various policy options that could influence behavior to mitigate the spread of an infectious disease. This is an important field to conduct research in, as the World Health Organization ranks communicable diseases among the top ten causes of death globally, with disproportionately greater mortality in low-income countries (World Health Organization, 2020). Especially given the extreme loss of life and gross domestic product resulting from the COVID-19 pandemic, it is crucial to understand optimal responses to the threat of an emerging disease outbreak in order to hopefully avert future crises of this magnitude.

The foundation of modern epidemiology largely rests on the work of William Kermack and Anderson McKendrick, who in 1927 published what has come to be known as the Susceptible-Infected-Removed (SIR) model for epidemics. In their baseline model, a population is divided into three segments: susceptible persons who have not been exposed to the disease; infected persons who are currently sick with the disease; and a third group of persons, colloquially termed "removed" or "recovered", who have either lived to gain immunity from future infection or have sadly passed away (Kermack and McKendrick, 1927). This work generalized upon previous efforts (Ross and Hudson, 1917) to codify the rules governing disease spread.

Economic epidemiology builds on the ideas of Kermack and McKendrick by applying the theory that human behavior both influences and is influenced by the prevalence of an infectious disease, with a feedback loop occurring if agents observe a disease spread and then adjust their behavior in ways that alter the spread of the disease itself. Knowing this, the government might choose to enforce policies, for instance lockdowns, randomized testing or social distancing mandates, in a way that might trigger such a feedback loop and ultimately lead to the dissipation of an epidemic.

An additional key application of economic theory to fighting epidemics centers around vaccination. Because there are positive externalities to individual vaccination, one would conventionally

expect there to be an opportunity for government policy to help achieve a socially optimal outcome. This is an important topic that has been the subject of extensive research, originating from Hethcote and Waltman, 1973 and Morton and Wickwire, 1974.

There are various topics for which there does not appear to be a great amount of existing research. I discuss three in the final section of this paper: firstly, how policy might be crafted to fight a mutating pathogen, where such mutations may significantly inhibit vaccine effectiveness or immunity from prior infection; secondly, how nations might invest in "pandemic insurance"; and thirdly, the long-term macroeconomic changes that may result from a shift in consumer preferences from the COVID-19 pandemic.

2. Discussion of Existing Literature and Models

Since the onset of the COVID-19 pandemic, a large and rapidly growing body of research has developed exploring different policy responses to curtail the spread of the disease or alleviate the economic harm caused by it. This section reviews in detail the many different topics under discussion, including context before and after COVID-19.

Social Distancing Behavior

Recent work on social distancing policy has put forth interesting and highly relevant results, particularly as the vaccine rollout is coming into full swing against COVID-19. Makris and Toxvaerd, 2020 investigate how expected social distancing levels change in response to a certain approaching vaccine rollout, compared to a certain approaching treatment development. What they find is that when the public expects a vaccine to be rolled out, social distancing behavior is expected to increase prior to the vaccine release date as people prioritize not becoming sick since they can be guaranteed immunity soon. However, when the public anticipates a perfect treatment to be released that completely cures sickness, the expected level of social distancing falls as the treatment arrival date approaches, and after the perfect

treatment is available, social distancing goes to zero since there is no longer an incentive to avoid being sick.

This finding builds upon previous efforts in Rowthorn and Toxvaerd, 2012 at describing the different effects and policy implications of treatment and prevention to an epidemic. There is plenty of other recent and related work on social distancing, for example Toxvaerd, 2020 which examines what endogenous social distancing equilibrium looks like towards the peak of a pandemic; additionally, McAdams, 2020 incorporates Nash Equilibria into the standard SIR framework to model people's decisions to engage in economic activity.

Vaccination

As mentioned previously, two key studies in the 1970s (Hethcote and Waltman, 1973 and Morton and Wickwire, 1974) kicked off economic analysis of vaccine policy by considering the standard Kermack and McKendrick SIR model in a situation where members of the susceptible population could become immunized to the epidemic. In these models, such immunization became a third way, besides death or recovery, that a person could transition into the final "removed" segment of the population, and the authors opened a discussion into the considerations the government faces in mandating vaccines to fight an epidemic.

Subsequent work (Fine and Clarkson, 1986; Stiglitz, 1988) expanded on Hethcote, Waltman, Morton and Wickwire's analyses to specifically consider the externality problem for vaccination, finding that the public's perception of a vaccine's risk leads to a level of vaccination that is less than socially optimal. This view has been generally held to be true, although Francis, 1997 dissented, finding that under special circumstances, the market for vaccinations is socially efficient. Later, Chen and Toxvaerd, 2014 rebutted, considering this finding to be "controversial" and reiterating that a vaccine externality will yield a suboptimal outcome if certain basic assumptions hold, for example vaccines being imperfect or agents being able to recover from infection.

Much work (e.g. Makris and Toxvaerd, 2020; Jones et. al., 2020; Alvarez et. al., 2020) has included the possibility of vaccination in models of the COVID-19 pandemic as a way to add complexity to other topics such as lockdown policy or social distancing behavior. A crucial finding mentioned in Rachel, 2020 is that having the possibility of a vaccine leads to "front-loaded" lockdowns that ultimately last for longer; notably, his extended version of the SIR model uses a case fatality ratio that increases with the number of infected to account for the overloading of health care resources. Similarly, Eichenbaum, 2020 also concludes that the expectation of a vaccine leads to an optimal policy of stringent restrictions to minimize fatalities until the vaccine is circulated.

Lockdowns

Lockdowns have long been an aggressive public health tool for stifling epidemics, and have been used around the world at various moments to combat COVID-19. A pre-COVID model of using lockdown control measures with an SIR framework was developed in Feng, 2007, where the author examined the metrics of peak and final epidemic sizes after different control strategies.

A more recent model in Acemoglu et al., 2020 considers the merits of more granular lockdown measures where the population is segmented according to vulnerability - in their discussion, "young", "middle-aged" and "old". The results were that granular policies that differentiated by age group were significantly superior to a one size fits all approach, with the best results occurring by imposing the strictest lockdowns for the most vulnerable segment of the population. Such a strategy keeps infection rates lower while also enabling less stringent lockdown measures for the remaining population segments.

Other recent work on this topic in Rachel, 2020 has uncovered some great insights, where the author makes the claim that the "infection externality" by itself influences people's behavior to such an extent that equilibrium social distancing is actually higher than optimal; as a result, the ideal lockdown policy should take this into account while minimizing cumulative deaths. This novel finding truly highlights the foundations of economic epidemiology, where people's behavior can and does change tangibly in response to an epidemic before any government regulation.

Monetary Policy and Fiscal Stimulus

In addition to the human cost of epidemics, there are often economic consequences associated with mitigation efforts such as lockdowns or social distancing. This is a vital topic that has not been neglected in the field, with considerable research done on what fiscal and monetary policy responses should be in an epidemic.

In the widely referenced Guerrieri et al., 2020, the authors focus on the theory of so-called "Keynesian supply shocks", i.e. shocks with significant feedback effects that trigger additional aftershocks in aggregate demand. In their view, the COVID-19 shock possibly is of a large enough magnitude to have this property. In responding to such an event, the authors note that routine fiscal stimulus can be less effective, since some sectors of the economy are shut down entirely. Instead, the authors propose forms of monetary policy, especially focusing on payments to the workers in the specific sectors seeing the greatest drop in economic activity.

Some lessons can also be learned from the Great Recession and the US fiscal policy response to that crisis. For example, Faria-e-Castro, 2018 started with a study of the averted GDP losses from the Great Recession policy response, and then expanded in Faria-e-Castro, 2020 to specifically consider policies in response to COVID-19 using a similar framework. In the most recent analysis, the author finds that the ideal tool for stabilizing borrowers' income are unemployment benefits, while alternatively liquidity assistance programs are ideal to stabilize employment in shut down sectors.

Testing

Adequate and thorough testing during an epidemic is an important ancillary measure that can be used in concert with other control techniques to make them more effective. An especially significant feature of COVID-19 that has allowed the virus to spread so rapidly is its ability to spread via asymptomatic or presymptomatic transmission. Testing is a direct solution to this, when infected persons can be detected as early as possible.

Relating to the COVID-19 pandemic, Berger et al., 2020 demonstrates how having additional information from testing can allow for improved outcomes in the form of lower death rates even with slightly less mitigation. This fact is important, and is a large reason why conventional public health strategies to fight COVID-19 have focused so much on rapid and reliable testing. Although the up-front costs to implementing testing capability can be significant, doing so ends up avoiding more economic loss in the future as the epidemic continues to spread.

As is the case with fiscal and monetary policy response, lessons can be learned from prior crises in the domain of testing as well. While the 2002 SARS epidemic did not feature the same type of virus that could spread so rapidly without symptoms, testing was still an important required component to diagnosis, as detailed in Chowell et al., 2003. Their study uses an enhanced version of Kermack and McKendrick's model known as "SEIR" - susceptible, exposed, infectious and removed. The additional category of "exposed" captures persons who are carrying the illness but cannot yet transmit it. Once they are able to transmit, they transition into the "infectious" category. This is a typical extension of the original SIR model that is also useful in describing COVID-19.

3. Discussion and Conclusion

The effects of the COVID-19 pandemic has set off a burst of new research in economic epidemiology that will no doubt continue for some time after the disease has subsided. Nevertheless, there are some elements of the field that have not received as much attention as perhaps is deserved. In this final section, I discuss three specific areas that could be of interest for future research: incorporating virus mutations into the standard SIR framework; country-level investments in what I call "pandemic insurance"; and the long-run economic consequences of the COVID-19 pandemic, specifically regarding changes in consumer preferences.

Epidemics with Mutating Pathogens

In conventional models for vaccines, it is typical to assume that a vaccine offers full immunity to infection. In many cases, even if this assumption does not perfectly hold, it may well be a weak enough assumption to serve as a legitimate foundation to a model that produces actionable insights. At first in the COVID-19 pandemic, the conventional assumption was that the vaccine would largely fit this description, and offer strong enough immunity to allow time for mitigation techniques to bring the virus under control.

However, recently it has become well-known that many "variants" of COVID-19 have surfaced around the world, which spawned as a result of random mutations. By chance, certain specific mutations could compromise the effectiveness of a vaccine or even partially nullify immunity from prior infection. If such a situation pans out where certain vaccines might no longer be effective against new variants, then it opens an important question into how mutations should be monitored as an epidemic spreads throughout a population, and how policy should be informed and adjusted accordingly. In standard models using temporal representation of an epidemic, new parameters of mutation rates or probability of vaccine ineffectiveness could be introduced.

Pandemic Insurance

Although serious pandemics are rare, they have incredibly severe costs associated with them. In the US alone, well over 500,000 lives have been lost to COVID-19. At a conservative figure of $5,000,000 for a statistical value of life, this amounts to a staggering $2.5 trillion loss, which is over 10% of US GDP. Similar to how individuals might choose to buy insurance to reduce the risk of excessive loss from a negative health outcome, countries might consider a similar system of "pandemic insurance". For example, perhaps by making prophylactic investments into testing and contact tracing infrastructure or health care equipment and surge capacity, countries can avoid some percentage of the economic loss from a pandemic if one hits.

When considering this topic, the questions of what specific measures should be invested in and how much to spend on investment are important. Reasonable estimates also should be made on the

likelihood of a pandemic occurring in a given year and its expected severity and economic impact should it occur. This could be another potential area for new research.

Long-run Economic Consequences of COVID-19

One notable and unexpected result of the COVID-19 pandemic seems to have been the shift in consumer preferences towards more digital-based interfaces and activities. For example, working from home could become more normal, even after the virus has subsided. What are the productivity gains or cost savings for firms and individuals who decide to work from home one or two days a week? These and related inquiries are important to study in order to understand the direction of future macroeconomic trends.

Economic epidemiology is a richly studied field that has seen even more attention since 2020. Although many new insights have been uncovered recently, there is still plenty of room for further developments into the additional topics described above. What is especially notable about most models used in the literature is how they extend upon the canonical SIR model first proposed by Kermack and McKendrick. After almost a century of research, their model remains the most widely used for exploring problems around disease control.

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