Do disease epidemics force economic activity underground? International evidence

Aziz N. Berdiev | Rajeev K. Goel | James W. Saunoris

Abstract
This article studies the impact of disease epidemics on the worldwide prevalence of the shadow or the underground economy. The informal sector has low entry barriers and provides an easy short-term option for the supply of goods and services during epidemics when traditional supply lines are cut or strained. Furthermore, the enforcement resources might be directed elsewhere during epidemics, lowering the expected costs of shadow operations. Using data for over 125 nations, we find that the incidence of epidemics positively and significantly contributes to the spread of the underground sector. These findings withstand a series of robustness checks.

KEYWORDS
COVID-19, economic development, epidemics, government, shadow economy

JEL CLASSIFICATION
I15, K42, E26, 017

1 | INTRODUCTION

Economics research on the impacts of disease epidemics has existed for some time (Adda, 2016; Becker, 1990; Prior & Stanhope, 1980). These issues have again come to a head with the recent and ongoing events related to the COVID-19 virus. Whereas various disciplines are grappling with the unexpected scale and scope of the challenges unleashed by the coronavirus, there are some longer-term and less immediate consequences that are not on the front burners of researchers’ and policymakers’ concerns. Yet, some of these impacts could persist over time and have adverse spillovers on other activities, making it important that attention is devoted to the understanding of their (possible) influences early on.

This paper focuses on one such possible impact of epidemics—the worldwide prevalence of the shadow economy. Due to its varied dimensions, encompassing both legal (e.g., income underreporting of otherwise legal operations) and illegal (e.g., smuggling) activities, the precise definition of the shadow economy (also called the informal economy, underground economy, or black market), what all it encompasses, and its measurement are all a matter of considerable debate (see, e.g., Schneider & Enste, 2013). In this article, we follow Medina and Schneider (2019, p. 4) and define the shadow economy as “all economic activities which are hidden from official authorities for monetary, regulatory and institutional reasons.” Hence, the shadow economy includes legal productive activity that would be included in the Gross Domestic Product (GDP) had it been reported, and, therefore, omits criminal sector activity.

Abbreviations: CRED, Centre for Research on the Epidemiology of Disasters; EM-DAT, Emergency Events Database; GDP, Gross Domestic Product; GEM, Global Entrepreneurship Monitor; GLS, generalized least squares; HT, Hausman–Taylor; MIMIC, multiple indicators, multiple causes.
The shadow economy persists in all nations of the world, with variations in its scope (Medina & Schneider, 2019; Schneider & Enste, 2013; Schneider et al., 2010), as individuals and firms try to evade regulations and taxes. The presence of the informal sector is challenging for governments both because it undermines tax collections, on the one hand, and compromises adherence to regulations and laws, on the other hand. Examples of shadow activities abound, including under-reported income by businesses, repairs by unlicensed contractors, smuggling of contraband, etc. Given its importance and prevalence, a substantial body of work has emerged on the causes or drivers of the underground sector (see Gérxhani, 2004; Goel & Nelson, 2016; Schneider & Enste, 2000 for literature surveys). Within this spectrum of possible determinants of the shadow economy, the influence of disease epidemics has not been considered and this forms the focus of this work.

Specifically, we use worldwide data to see whether, and to what extent, the incidence of disease epidemics impacts the shadow economy. About 14 percent of 125-odd nations in our sample faced a biological epidemic from 1995 to 2017 (www.cred.be; Tables 1 and A1). While the underlying source of the disaster data has broad information on natural and technological (manmade) disasters [The Centre for Research on the Epidemiology of Disasters (CRED; www.cred.be)], we chose to focus on biological epidemics because such disasters have direct relevance to the current COVID-19 crisis. Another advantage of obtaining the data from a single source is that the disasters are consistently coded (and not prone to disproportionate media focus on only large disasters).

Adding to the emerging body of research related to the current coronavirus crisis (Baldwin & Weder di Mauro, 2020; Farzanegan et al., 2021), this article studies the impact of disease epidemics on the worldwide prevalence of the underground economy. Due to the breakdown of efficient institutions and a sudden loss of employment, individuals and firms are likely to find the move to the underground sector attractive. In some instances, governments have imposed lockdowns on business operations to contain the virus (Alfano & Ercolano, 2020; Kumar et al., 2021), with spillovers onto underground activities. The breakdown of institutions or a shift in government’s focus away from enforcement to finding a cure for the epidemic lowers the potential costs of underground operations, while the unemployed find easier entry into the informal sector. This is especially true when epidemics temporarily close some of the training centers for the unemployed to retrain and reenter the formal labor force.

If it turns out that epidemics end up increasing the shadow sector, there would be a consequent downward impact on governments’ efforts to contain epidemics both via a resource constraint (low tax collections) and a lessened ability to monitor compliance with health and safety regulations. Moreover, to the extent that individuals are evading stay-at-home orders and participating in the shadow economy, this may undermine efforts to contain the spread of the disease.

The key question addressed in this research is: Does the prevalence of disease epidemics significantly impact the prevalence of the shadow economy?

Besides answering the above question using time series data for over 125 nations, the analysis will draw recommendations for related policies in the times of disease epidemics (or pandemics like the current coronavirus; https://www.weforum.org/agenda/archive/covid-19). Placing the formal empirical analysis within the significant cross-national determinants of the shadow economy, our results show that the incidence of epidemics increases the size of the shadow economy. Numerically, the occurrence of an epidemic increases the size of the shadow economy (as a percentage of GDP) by 0.74 percentage points. The main implication of our findings is that while saving lives and quick economic recovery would be the primary policy goals during pandemics, policymakers should also take account of the spillovers on the underground markets as the transition to underground activity makes fighting epidemics challenging. Overall, these findings withstand a series of robustness checks.

The structure of the rest of this paper includes the literature review and hypothesis in the next section, followed by the empirical model, data, results, and conclusions.

2 | THEORETICAL DISCUSSION AND HYPOTHESES

In this paper, we are interested in understanding the shadow economy’s response to biological disasters classified as epidemics. The onset and spread of epidemics are largely uncertain. So, broadly speaking, one could view the analysis in the context of a shock to the economy, with both macro- and micro-economic implications. In the context of the shadow economy—epidemics relation, one could view the macro impacts being on institutions and government resources, whereas the micro impacts would be on individuals’ health and employment. All of these potentially impact the propensities to operate in the underground sector.
In particular, there are numerous channels through which one could envision how epidemics could impact the underground sector (https://medicalxpress.com/news/2020-05-coronavirus-response-isnt-billion-people.html). One, epidemics impact the smooth functioning of government institutions—both devoted to enforcement of rules and awarding of punishments. This emboldens potential lawbreakers, with their potential net benefits from breaking the law increasing (see Becker, 1968). Two, government efforts to contain the spread of viruses create regional “islands” that are somewhat autonomous, again presenting opportunities for some to evade paying taxes or adhering to regulations. These pockets or islands are not necessarily created by geographic distances but might be the result of governments favoring certain areas of high virus prevalence/transmission (e.g., capital cities). Breakdowns in communications networks following epidemics might also result in such isolated areas. The presence of such pockets might engender barter transactions, which cannot be traced by tax officials. Third, in times of crises posed by epidemics, market functions are disrupted, providing opportunities for entry to unauthorized or shadow agents. Anecdotal evidence exists under the current COVID-19 crisis with instances of unauthorized (home) barber shops, in-home informal tuitions, unauthorized ambulance or taxi services, etc.

There may be (adverse) health impacts of the shadow sector in times of epidemics. On the one hand, the spurt of shadow suppliers to provide special health and safety equipment likely does not meet the official standards or norms; on the other hand, shadow workers, lacking social health protections, are more likely to continue working while infected, thus contributing to the spread (and longevity) of an epidemic. These issues warrant policies to check the shadow sector in an epidemic, beyond the traditional arguments related to plugging the leakages of tax revenues.

Furthermore, the counter-cyclical relationship between shadow economies and formal sector business cycles, as shown by Elgin (2012), is likely to exist as epidemics depress the formal sector. Shadow economies serve as an economic buffer to absorb the over- or under-capacity in the formal sector. During economic recessions, the shadow economy offers an attractive alternative for earning income among the unemployed individuals, especially to prevent losing unemployment insurance benefits. In other words, unemployed individuals might prefer to work in the shadow sector in order to earn additional income that is concealed from the government. Whereas Raddatz (2007) provides evidence that epidemics lower formal economic activity, we argue that epidemics might drive individuals to the shadow economy. It is perhaps expected that the underground economy provides refuge for individuals who lose formal sector employment (see, e.g., Bajada & Schneider, 2009; Dell’Anno & Solomon, 2008).

One could also argue that the demand for goods and services in the shadow economy might rise during epidemics as economic participants are more likely to purchases goods and services in the shadow economy, since they are, on average, less costly than formal sector goods and services and of similar quality (Schneider & Enste, 2013). In addition, the shutdowns implemented by governments following disease epidemics might make certain formal sector goods and services unattainable, thereby inducing shadow participants to step in to meet these demands.

Another reason might be that firms may partially or fully transition to the underground sector in order to save resources and/or cut costs. Indeed, during the current COVID-19 pandemic, many small businesses are deciding to defy government orders to remain closed by continuing to serve their customers. Small businesses face special challenges as they lack direct access to financing from capital markets. Furthermore, increased demand combined with anti-price gouging laws that result in shortages of necessary goods and services during epidemics (e.g., face masks [Goel & Haruna, 2021], disinfectants, etc.) offer unique opportunities for budding shadow entrepreneurs. In such cases, there may be a symbiotic relationship between the formal and informal sector to utilize different channels and networks to supply necessary goods and services. For example, formal businesses may utilize informal sector supply chains to deliver goods. All of these reasons suggest that the incidence and spread of epidemics might drive individuals and businesses to the shadow economy.

Epidemics also strain public services, directing some government resources toward combating the spread of disease. When some of these directed resources involve enforcement personnel (e.g., police used to check compliance with special health and safety mandates to combat the epidemic), the expected costs of underground operations (and other illegal acts) would go down (as there are diminished chances of getting caught). This would increase participation in the shadow sector by emboldening potential shadow entrants.

Moreover, the uncertain diffusion (both in the timing and intensity of penetration) of an epidemic creates decision-making uncertainties for firms with regard to their interactions with customers and suppliers. How long will the epidemic last and how far it would spread? This leads to, among other things, strained supply chains leading to unreliable and incomplete delivery of inputs (Goel, Mazhar, & Saunoris, 2021). Given the generally unprecedented nature of most epidemics, this accompanying uncertainty would render traditional contracts (both with suppliers and/or customers) incomplete (see Tirole, 1999, 2009). To overcome the perceived short-term shortages in the delivery of vital
inputs and to offload produced goods that are no longer readily being picked up by contracted customers, firms are likely to resort to informal sector suppliers/customers. The informal sector, with its low entry barriers, low costs, and a lack of adherence to regulations, provides an easy option for firms in the short term. Thus, this is another channel of the influence of disease epidemics onto the underground sector.

There is a possibility, however, that epidemics can reduce the size of the underground sector. For example, risk aversion by consumers during epidemics can make the informal sector products less desirable than those in the formal sector (e.g., consumers might find hand sanitizers produced by informal sector firms to be relatively less effective). Furthermore, the relative returns in the formal versus informal sectors might change during epidemics to induce the migration of some firms from the informal sector to the formal sector. Lastly, nations differ in their focus on certain industries, given their comparative advantages, and certain industries prosper while others languish during epidemics. The different switching costs between the formal and informal sectors, different substitutability of inputs across industries (Goel, 1990), and differing entry barriers might make informal sector activity decrease in some nations. Thus, the overall impact of epidemics on the underground sector is unclear and the empirical analysis will inform us.

Based on the above discussion, we frame our hypotheses that we test using annual data from a large set of nations:

**H1a:** Greater prevalence of disease epidemics would increase the size of the shadow economy when positive spillovers of epidemics on the informal sector outweigh the negative spillovers, ceteris paribus.

**H1b:** Greater prevalence of disease epidemics would decrease the size of the shadow economy when negative spillovers from epidemics on informal markets exceed the positive spillovers, ceteris paribus.

In addition to the tie to the shadow economy literature, this work also adds to the economics of epidemics (Adda, 2016; Kahn, 2005; Ma et al., 2020; Rasul, 2020), or more broadly, to the effects of macroeconomic shocks (Noy, 2009). This body of work, with a renewed focus on COVID-19 in recent months (see Baldwin & Weder di Mauro, 2020; Beyer et al., 2021; Farzanegan et al., 2021; Goel, Mazhar, & Saunoris, 2021; Goel, Nelson, & Goel, 2021; Jordá et al., 2020), has in the past mostly focused on the impacts of specific epidemics and/or specific regions (Armien et al., 2008; Bloom & Mahal, 1997; Folgi & Veldkamp, 2019; Hasala et al., 2012; Prior & Stanhope, 1980). The broad consideration of various epidemics over time in regard to their impact on the underground economy is unique to this work. Given the current COVID-19 crisis, and the worldwide development of the shadow economy, understanding the spillovers from epidemics on underground economic activity could have important implications for current economic policies. We turn next to the empirical model and data.

### 3 | EMPIRICAL MODEL AND DATA

#### 3.1 | Empirical model

To test the above hypotheses and to focus on the key influence of epidemics, the general model to explain the size of the shadow economy for country \( i \) (\( i = 1, ..., 126 \)) and time \( t \) (\( t = 1995, ..., 2017 \)) is:

\[
\text{Shadow}_{it} = \beta_0 + \beta_1 \text{Epidemic}_{it} + \gamma_i X_{it} + \theta_i Z_i + \mu_i + \varepsilon_{it}
\]

(1)

where \( \mu_i \) is the country-specific effect that accounts for heterogeneity across countries related to, for example, cultural differences that are mostly fixed over our time of study yet likely influence the spread of epidemics and the size of the shadow economy. The dependent variable is the size of the shadow economy as a percent of GDP (Shadow). This variable is estimated by Medina and Schneider (2019) for 158 nations from 1991 to 2017. In this paper, we posit that the occurrence of epidemics in countries related to infectious diseases (i.e., bacterial, viral, fungal, and prion) have an important influence on the decisions of individuals and firms to move underground. To account for this unique aspect, we include the number of epidemics (Epidemic) as our main independent variable.

To isolate the impact of epidemics on the shadow economy, we borrow from the extant literature and control for a variety of other factors that influence the size of the shadow economy (Gërxhani, 2004; Goel & Nelson, 2016; Schneider & Enste, 2000). These control variables are both time-varying (\( X_{it} \)) and time-invariant (\( Z_i \)).

The time-varying controls include formal economic growth (ECgrowth) to account for the health of the formal sector economy, the degree of freedom measured as political (PolFreedom) and economic (EconFreedom), and the quantity, or size, of the government (GovtSize), and the quality of government (BureauQual). Strong economic growth
TABLE 1 Variable definitions, data sources, and summary statistics

| Variable   | Description [observations; mean; standard deviation]                                                                                                                                                                                                 | Source                        |
|------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|
| Shadow     | The size of the shadow economy as a percent of GDP, measured using the multiple indicators, multiple causes (MIMIC) method. [2654; 28.80; 12.95]                                                                                                           | Medina and Schneider (2019)   |
| Epidemic   | The number of epidemic incidences by year between 1995 and 2017. Epidemics caused by infectious diseases that are categorized as viral, bacterial, fungal or prion. [2654; 0.32; 0.76]                                                                         | Emergency Events Database     |
| ECgrowth   | Economic growth, measured as the log difference of per capita real GDP. [2654; 2.19; 3.80]                                                                                                                                                                                                                 | The World Bank (2018)         |
| PolFreedom | Index of political freedom, measured as the sum of civil liberties and political rights. This index is rescaled from −2 to −14 so that higher numbers denote more political freedom. [2654; −6.21; 3.62]                                              | Freedom House                |
| BureauQual | Index of bureaucratic quality, measuring the strength and quality of bureaucracy on a 0-4 scale, with higher numbers denoting a higher quality. [2654; 2.31; 1.09]                                                                                              | International Country Risk Guide |
| GovtSize   | Government size, measured as government final consumption expenditures as a percent of GDP. [2654; 20.53; 7.75]                                                                                                                                                          | The World Bank (2018)         |
| EconFreedom| Index of economic freedom on a scale from 0 to 100, with higher numbers denoting more freedom. [2654; 61.64; 9.98]                                                                                                                                                   | Heritage Foundation (2017)    |
| Federal    | Dummy variable equal to one if the country is classified as “Federal” and zero otherwise. [2654; .015; 0.36]                                                                                                                                                     | Treisman (2002)               |
| EthnicINQ  | Ethnic income inequality measured as the Gini index capturing the mean income across ethnic groups. [2654; 0.43; 0.24]                                                                                                                                 | Alesina et al. (2016)        |
| Shadow2    | The number of newly unregistered business as a percent of the working-age population. [265; 3.72; 3.43]                                                                                                                                                      | Dau and Cuervo-Cazurra (2014)  |
| RuleLaw    | Index of the rule of law on a scale from −2.5 to 2.5, with higher numbers denoting stronger rule of law. This is a perceptions based index capturing the degree to which people abide by the rules of society, quality of contract enforcement, property rights, police, courts and the likelihood of crime. [2236; 0.12; 1.00] | Kaufmann et al. (2010)       |
| UNEMP      | Unemployment rate (%). [1946; 7.91; 4.93]                                                                                                                                                                                                                         | The World Bank (2018)        |
| EDUC       | Primary school enrollment, as a percent of gross enrollment. [2286; 101.81; 13.76]                                                                                                                                                                       | The World Bank (2018)        |
| GovStability| Index of government stability, measuring the government’s ability to carry out programs and stay in office based on government unity, legislative strength and population support. The index is measured on a 12-point scale, with higher numbers denoting less risk. [2654; 8.26; 1.60] | International Country Risk Guide |
| Deaths     | The number of deaths per one million population caused by epidemics. [2526; 3.28; 32.74]                                                                                                                                                                   | Emergency Events Database     |

Note: Summary statistics based on all available data from 1995 to 2017.

*Emergency Events Database (EM-DAT) is from the Centre for Research on the Epidemiology of Disasters (www.cred.be).

in the formal sector raises the opportunity cost of producing underground. Greater political freedom gives the power of voice to citizens in encouraging elected officials to behave in a favorable way and reduce the need to transition to the underground sector. Likewise, more economic freedom (e.g., low taxes and regulations) in the formal sector diminishes the relative benefits of the underground economy relative to the formal economy (Berdiev et al., 2018). The strength and quality of institutions, proxied by bureaucratic quality, improve the workings of the formal sector and thus reduce the impetus for underground activities (Berdiev et al., 2020; Dreher et al., 2009; Torgler & Schneider, 2009). Lastly, the size of government can have various impacts, including growing the shadow economy if government intrusion encourages people to move underground and when government projects are subcontracted to underground firms, or shrinking the shadow economy if the government uses its resources to combat shadow activities (Goel & Nelson, 2016).
Regarding the time-invariant variables in $Z_i$, we account for government decentralization (Federal) and ethnic diversity, measured as the degree of income inequality across ethnic groups (EthnicINQ). Greater government decentralization likely leads to a more efficient government and better oversight of government officials that reduce the incentive to evade taxes and produce underground (Dell’Anno & Teobaldelli, 2015). More ethnic diversity in terms of economic inequality increases the likelihood that governments, for example, resort to policies that favor income redistribution over the production of public goods and services that would increase the incentive to produce underground (Berdiev et al., 2020).

The usual way to estimate Equation (1), given the unobserved country-specific effect $\mu_i$, is to use either the random-effects model or the fixed-effects model. The random-effects model uses a Generalized Least Squares (GLS) transformation of the variables and assumes that none of the explanatory variables are correlated with the individual effect. The fixed-effect model assumes that all the explanatory variables are correlated with the individual effect and therefore uses the within transformation to purge the individual effect from the model; however, this transformation also removes the time-invariant variables in $Z_i$ in Equation (1).

An alternative, or intermediate, approach was developed by Hausman and Taylor (1981), known as the Hausman–Taylor (HT) estimator, which is based on an instrumental variables approach that allows only some of the variables to be correlated with $\mu_i$. This estimator has the added benefit in that it allows us to estimate the effect of the time-invariant variables $Z_i$. The HT approach divides the time-varying variables ($X_{it}$) and time-invariant variables ($Z_{it}$) into exogenous variables ($X_1$ and $Z_1$) and endogenous variables ($X_2$ and $Z_2$). Country-specific fixed effects (e.g., culture and geography) are most likely to influence economic development and institutions, as well as the incidence and spread of epidemics. Therefore, the endogenous variables that are assumed to be correlated with the individual fixed effects $\mu_i$ and uncorrelated with the random error $\epsilon_i$ include $ECgrowth$, $BureauQual$, $GovtSize$ and $Epidemic$ in $X_2$, and $EthnicINQ$ in $Z_2$. The exogenous variables in $X_1$ include $EconFreedom$ and $PolFreedom$, and Federal is in $Z_1$.

The HT estimator first performs a GLS transformation to the variables in Equation (1) using the estimated variance-covariance matrix of the residual component $\mu_i + \epsilon_i$ and then applies 2SLS estimation to the transformed equation (for details see Baltagi, 2008; Wooldridge, 2002). The variables used to instrument the endogenous variables include the time-demeaned variables in $X_1$ and $X_2$, the mean of the variables in $X_1$, and the variables in $Z_1$ (see Breusch et al., 1989). The order condition for identification requires that $X_1$ has at least as many variables as $Z_2$ (i.e., the number of exogenous time-varying variables is greater than or equal to the number of endogenous time-invariant variables), which makes the HT estimator more efficient than the FE estimator (Baltagi et al., 2003). Because we have more variables in $X_1$ relative to $Z_2$, our model is overidentified. The Sargan–Hansen test for overidentification in the baseline Model 2.1 of Table 2 fails to reject the null hypothesis that the instruments are valid ($p$-value = 0.707).

To determine the correct model to use to estimate Equation (1), we first report the Hausman test to distinguish between the random effects and fixed effects model. A rejection of the null evidence that the independent variables are correlated with the country effect ($\mu_i$) and thus fixed effects is the preferred model. Next, we perform a Hausman test to distinguish between the fixed effect model and the HT model. Failure to reject the null hypothesis in this case suggests that the HT estimator is superior. The results, reported at the bottom of Table 2, show a rejection of the null in the first Hausman test and a failure to reject the null in the second Hausman test, therefore the HT estimator is the preferred estimator to estimate Equation (1). The Chi-square test reported at the bottom of Table 2 shows that the coefficients are not jointly equal to zero.

### 3.2 Data

The data set is a panel of 126 countries observed annually from 1995 to 2017—see Table A1 for a list of countries used in the analysis. Although the data pre-date the current pandemic, the period of the analysis is instructive for framing policies in times of the current coronavirus crisis.

The clandestine nature of the underground economy necessitates creative ways to uncover underground activities (see Schneider & Buehn [2013] for a review). Indirect approaches for estimating the shadow economy include, for example, the currency demand approach and the physical input approach. The currency demand approach assumes that taxes are the driving force behind shadow participation; thus, the difference in currency demand under high and low tax settings provides an estimate for the currency used to support shadow activities (see, e.g., Cagan, 1958; Tanzi, 1983). The physical input approach assumes that growth in electricity consumption and growth in total economic activity move in lockstep, therefore, the difference between the growth in electricity consumption and growth in
GDP offers an estimate for the growth in the shadow economy (see, e.g., Kaufmann & Kaliberda, 1996). One of the main problems with these two means of estimating the size of the shadow economy is they are based on a single indicator. A more comprehensive approach in estimating the size of the shadow economy that has gained popularity in recent years is the multiple indicators, multiple causes (MIMIC) method, which, as the name suggests, is based on multiple indicators of the shadow economy (see, for details, Medina & Schneider, 2019; Schneider, 2010; Schneider et al., 2010). The MIMIC method uses covariance information from several observable causal and indicator variables to estimate the latent shadow economy. Specifically, the MIMIC method is a structural-equations model that is comprised of two equations, the structural model that links the causal variables to the shadow economy, and the measurement model that links the shadow economy to the indicator variables. Our measure of the shadow economy comes from Medina and Schneider (2019), who use the MIMIC method to provide the most recent estimates of the shadow economy for a large panel of nations. This estimate of the shadow economy is an improvement on the widely used measure of the shadow economy from Schneider et al. (2010). According to this estimate of the shadow economy, in our sample the average size of the shadow economy is approximately 29% of GDP (with considerable variation across countries), with a high of 71% (Bolivia) and a low of 5% (Switzerland).

Data on epidemics related to biological disasters is from the Emergency Events database (EM-DAT) from the CRED (www.cred.be). This database, which has been utilized extensively by prior studies (see, e.g., Kahn, 2005; Noy, 2009; Raddatz, 2007), and includes epidemics related to infectious diseases (including viral, bacterial, fungal, and prion) from 1900 to 2020 for 160 countries. According to this data set, approximately 57% of epidemics are bacterial diseases, 40% are viral diseases, and 3% are parasitic diseases. Among the most common epidemics were caused by Cholera, Dengue, and Meningococcal disease. Based on the start and end date of each epidemic identified in this database for each country and each year, we create a variable that captures the number of epidemic incidences (Epидemic) by country and year. India experienced the highest incidence of epidemics over the 1995−2017 time period. Also, the correlation between Shadow and Epidemic is 0.30. Figures A1 and B1, respectively, show the incidence of epidemics and the prevalence of the shadow economy.

The other variables used in the analysis are from reputed international sources that are routinely used in the literature. Complete details about variable definitions, summary statistics and data sources are provided in Table 1.

4 | RESULTS

4.1 | Baseline results

We test the impact of Epidemic on the shadow economy and present the baseline regression estimates in Model 2.1 of Table 2. This enables us to test hypothesis H1.

The results show that the coefficient on Epidemic is positive and statistically significant at the 1% significance level, thereby suggesting that epidemic incidences increase the size of the shadow economy. Epidemics prompt individuals and firms to move underground as a means to maintain operations and earn/maintain income. Furthermore, during epidemics, the focus of nations likely shifts away from controlling the shadow economy, which lowers the expected costs of operating underground. Numerically speaking, the occurrence of an epidemic increases the size of the shadow economy (as a percentage of GDP) by 0.74 percentage points. This finding thus confirms our hypothesis H1a that epidemics are positively linked with shadow development.

To better visualize the influence of epidemics on the shadow economy, we conduct a simulation exercise for a select number of OECD and Non-OECD countries. In particular, we suppose that the listed countries experience one to five epidemics and report the size of the shadow economy following the event. These results are reported in Table A2.

Turning to the control variables, the coefficients on ECgrowth, EconFreedom, and Federal are negative and statistically significant. As expected, prosperous countries have strengthened enforcement and higher opportunity costs of operating underground. Furthermore, institutions that support policies to promote government decentralization and economic freedom curb underground participation. The coefficient on EthnicINQ is positive and statistically significant, which coincides with more ethnically-diverse countries in terms of income inequality are more likely to favor redistribution policies or policies that benefit specific ethnic/income groups that would encourage underground participation (Berdiev et al., 2020). Other influences such as PolFreedom, BureauQual, and GovtSize are statistically insignificant at conventional levels. Greater political freedom or a higher degree of democracy is tied to a due legal process, which is
Table 2: Disease epidemics and the shadow economy: baseline and extended models. Dependent variable: Shadow

| Variable     | Baseline (2.1) | Extended models (2.2) | (2.3) | (2.4) |
|--------------|----------------|------------------------|-------|-------|
| **Epidemic** | 0.740***       | 0.740***               | 0.131*| 0.130*|
|              | (0.080)        | (0.080)                | (0.074)| (0.074)|
| **PolFreedom** | -0.232         | -0.236                 | 0.040 | 0.038 |
|              | (0.174)        | (0.175)                | (0.088)| (0.089)|
| **EconFreedom** | -0.177***      | -0.177***              | -0.050*| -0.049*|
|              | (0.063)        | (0.063)                | (0.029)| (0.029)|
| **ECgrowth** | -0.073***      | -0.073***              | -0.105***| -0.105***|
|              | (0.026)        | (0.026)                | (0.016)| (0.016)|
| **BureauQual** | 0.124          | 0.121                  | -0.489**| -0.491**|
|              | (0.576)        | (0.577)                | (0.216)| (0.216)|
| **GovtSize** | 0.030          | 0.029                  | 0.225***| 0.225***|
|              | (0.082)        | (0.083)                | (0.038)| (0.038)|
| **Federal**  | -7.993***      | -7.386**               | -8.206***| -6.686**|
|              | (2.790)        | (3.204)                | (2.949)| (2.980)|
| **EthnicINQ** | 41.363***      | 37.987***              | 43.729***| 33.534***|
|              | (11.924)       | (14.392)               | (7.614)| (8.957)|
| Regional effects | No           | Yes                    | No     | Yes   |
| Time effects  | No             | No                     | Yes    | Yes   |
| Hausman test: FE versus RE | [0.000] | [0.000]               | [0.000]   | [0.000]   |
| Hausman test: FE versus HT  | [1.000]       | [1.000]                | [0.925]  | [0.925] |
| Chi-square test | [0.000]       | [0.000]               | [0.000]  | [0.000] |
| Observations  | 2654           | 2654                   | 2654    | 2654   |
| Number of countries | 126          | 126                    | 126     | 126    |

Note: See Table 1 for variable details. Constant is included in each model, but not reported. Each model is estimated using the Hausman–Taylor estimator where “a” denotes an endogenous variable. Cluster-robust standard errors are in parentheses and probability values are in brackets.

*p < .1, **p < .05, ***p < .01.

often lengthy. This delay lowers the expected value of punishment for operating underground. Moreover, government size and quality likely have offsetting influences on the shadow economy. Overall, the results for the control variables are broadly consistent with the literature (e.g., Berdiev et al., 2018; Dreher et al., 2009; Goel & Nelson, 2016).

In Models 2.2–2.4, we extend the baseline model to control for region- and time-specific influences by augmenting the baseline model with regional and year dummies. In Model 2.2, which controls for regional effects, the results are very similar to the baseline model. However, once time effects are controlled for in Models 2.3–2.4, the results show some interesting differences. For instance, the coefficient on Epidemic is considerably smaller in magnitude and relatively less statistically significant. Furthermore, consistent with government overreach prompting underground participation, the coefficient on GovtSize is now positive and statistically significant, while better quality (BureauQual) of government reduces the size of the shadow economy. Overall, these results support the baseline model results while controlling for other aspects.

To test the validity of our results, we conduct several robustness checks to account for the following: additional control variables, alternate shadow economy measure, the potential impact of outliers, the possible simultaneity between epidemics and the shadow economy, and the potential simultaneity between economic growth and the shadow economy. Furthermore, we account for country-specific time trends and control for the severity of epidemics, measured by the number of deaths caused by epidemics. Lastly, we address potential heterogeneity by splitting the full sample.
into (i) non-island and island nations, (ii) non-OECD and OECD nations, and (iii) not economically free and economically free nations. The regression estimates for the robustness checks are reported in Tables 3–6.

### 4.2 Considering additional control variables

As our first robustness check, we account for additional control variables, namely, the strength of the rule of law (RuleLaw), the unemployment rate (UNEMP), the level of education (EDUC), and the risk associated with government instability (GovStability). A consistent rule of law increases the potential punishments for breaking the law and we would expect nations with a strengthened rule of law to have a smaller shadow economy, ceteris paribus (e.g., Dreher et al., 2009; Torgler & Schneider, 2009). Likewise, a higher risk of government instability is likely to encourage individuals to migrate underground. Such migration could also be across international borders (Goel & Saunoris, 2014; Table 3

|                      | (3.1)            | (3.2)            | (3.3)            | (3.4)            |
|----------------------|------------------|------------------|------------------|------------------|
| Epidemic             | 0.771***         | 0.635***         | 0.646***         | 0.507***         |
|                      | (0.102)          | (0.146)          | (0.108)          | (0.085)          |
| PolFreedom           | −0.007           | −0.220           | −0.193           | −0.206           |
|                      | (0.170)          | (0.221)          | (0.182)          | (0.165)          |
| EconFreedom          | −0.149**         | −0.173***        | −0.170**         | −0.161***        |
|                      | (0.063)          | (0.059)          | (0.068)          | (0.055)          |
| ECgrowth             | −0.047*          | −0.004           | −0.049*          | −0.096***        |
|                      | (0.027)          | (0.028)          | (0.025)          | (0.024)          |
| BureauQual           | 0.030            | 0.336            | −0.054           | 0.500            |
|                      | (0.726)          | (0.725)          | (0.601)          | (0.588)          |
| GovtSize             | 0.040            | −0.003           | 0.058            | 0.053            |
|                      | (0.078)          | (0.100)          | (0.093)          | (0.074)          |
| Federal              | −7.765***        | −8.873***        | −7.900***        | −8.344***        |
|                      | (2.928)          | (2.902)          | (2.737)          | (2.918)          |
| EthnicINQ            | 46.327***        | 46.045***        | 41.679***        | 43.045***        |
|                      | (12.876)         | (12.026)         | (12.848)         | (11.896)         |
| RuleLaw              | −1.822           |                 |                 |                 |
|                      | (1.121)          |                 |                 |                 |
| UNEMP                |                  | 0.368***         |                 |                 |
|                      |                  | (0.069)          |                 |                 |
| EDUC                 |                  |                  | −0.045          |                 |
|                      |                  |                  | (0.028)         |                 |
| GovStability         |                  |                  |                  | 0.729***         |
|                      |                  |                  |                  | (0.068)          |
| Observations         | 2236             | 1946             | 2286             | 2654             |
| Number of countries  | 126              | 124              | 123              | 126              |

Note: See Table 1 for variable details. Constant is included in each model, but not reported. Each model is estimated using the Hausman–Taylor estimator where “a” denotes an endogenous variable. Cluster-robust standard errors are in parentheses.

*p < .1, **p < .05, ***p < .01.
Disease epidemics and the shadow economy: additional robustness checks

| Robustness checks → | R2: alternate shadow measure | R3: accounting for outliers | R4: accounting for simultaneity | R5: without \( EC \) growth \
| Dependent variable → | \( Shadow2 \) (4.1) | \( WShadow \) (4.2) | \( Shadow \) (4.3) | \( Shadow \) (4.4) |
|---------------------|-----------------|-----------------|-----------------|-----------------|
| \( Epidemic^a \) | 0.340 (0.278) | | 0.749*** (0.079) | |
| \( WEpidemic^a \) | 0.809*** (0.111) | | | |
| \( Epidemic_{t-1}^a \) | | 0.477*** (0.084) | | |
| \( PolFreedom \) | 0.098 (0.188) | -0.239 (0.173) | -0.230 (0.178) | -0.255 (0.176) |
| \( EconFreedom \) | -0.117* (0.068) | -0.191*** (0.056) | -0.179*** (0.063) | -0.168*** (0.063) |
| \( ECgrowth^a \) | -0.045 (0.029) | -0.071*** (0.026) | -0.076*** (0.027) | |
| \( BureauQual^a \) | -0.204 (0.645) | 0.189 (0.550) | 0.111 (0.582) | 0.129 (0.571) |
| \( GovtSize^a \) | 0.112 (0.167) | 0.033 (0.082) | 0.025 (0.083) | 0.030 (0.082) |
| \( Federal \) | -3.190 (2.149) | -7.783*** (2.753) | -7.972*** (2.801) | -7.973*** (2.798) |
| \( EthnicINQ^a \) | 20.927 (16.675) | 40.525*** (11.822) | 41.498*** (11.992) | 41.514*** (11.977) |
| Observations | 266 | 2654 | 2654 | 2654 |
| Number of countries | 60 | 126 | 126 | 126 |

Note: See Table 1 for variable details. Constant is included in each model, but not reported. Each model is estimated using the Hausman–Taylor estimator where “a” denotes an endogenous variable. Cluster-robust standard errors are in parentheses.

\( ^a p < .1, ^* p < .05, ^{**} p < .01 \)

Goel et al., 2020). Greater educational attainment promotes understanding and adherence to the laws, while making entry into the formal labor force easier (e.g., Berdiev & Saunoris, 2018; Loayza et al., 2009). Both of these factors would check the informal sectors. Finally, the unemployed have a higher propensity to enter the informal sector (e.g., Bajada & Schneider, 2009; Dell’Anno & Solomon, 2008).

We add these additional control variables, one at a time, to our baseline models and report the results in Table 3. First of all, the positive impact of epidemics on the shadow economy that was shown in the baseline models, remains and is statistically significant in all models. Thus, the incidence of epidemics contributes to the spread of shadow operations, and these results withstand the inclusion of additional covariates.

Furthermore, the results for rule of law and education are consistent with intuition (albeit fail to gain statistical traction at conventional levels of significance)—greater educational attainment and rule of law reduce the size of the shadow economy. The result for unemployment, showing the expected positive and statistically significant effect, implies that a greater number of people unemployed may look to the underground to make ends meet. Finally, government stability increases the size of the shadow economy. Conceivably, a stable government is more likely to grow in size (higher taxes and regulations) that might induce individuals and firms to move to the informal sector.
A stable governments also increases business optimism, both in the formal and informal sectors. This aspect warrants further investigation. The results with respect to the other controls largely support the baseline model (Model 2.1).

### 4.3 Considering an alternate measure of the shadow economy

Measuring the size of the shadow economy is a difficult endeavor due to the inherent unreported nature of shadow activities. Consequently, we check the robustness of the baseline findings to an alternative, though narrower, measure of the shadow economy, which focuses on newly formed underground businesses. Dau and Cuervo-Cazurra (2014) estimate the prevalence of newly unregistered businesses as a percent of the working-age population by subtracting the number of newly registered (formal) businesses as a percent of working-age population collected from the World Bank Group Enterprise Survey from the estimate of total (formal plus informal) new businesses from Global Entrepreneurship Monitor (GEM). GEM does not inquire about registration status, therefore it is assumed that this measure captures both formal and informal businesses.11

We replaced the dependent variable with this alternate measure of the shadow economy (Shadow2) and re-estimated the baseline model. The results are reported in Model 4.1 of Table 4. The coefficient on Epidemic is positive, which is consistent with the baseline model; however, the coefficient is not significant at conventional levels ($p$-value $= 0.22$)—note that the sample size is significantly smaller consisting of about half the countries. The remaining controls lack statistical significance, except that the coefficient on economic freedom is negative and statistically significant. Therefore, using a narrow measure of the shadow economy for a much smaller sample, these results are broadly in line with the baseline findings.
4.4 | Accounting for possible impact of outliers

It is possible that some nations might have an abnormally high number of epidemic incidences or large shadow economies. The large variation in the incidence of epidemics is also evident in the current case of COVID-19 (https://coronavirus.jhu.edu/map.html). Accordingly, as a robustness check, we account for the possible influence of outliers by winsorizing the dependent variable and the epidemics variable. Winsorizing generates a new variable that replaces the top first percentile and bottom 99th percentile of the variable with the next variable counting inward (for details see Barnett & Lewis, 1994).

We re-estimated the baseline models using the winsorized variables and present the results in Model 4.2 of Table 4. The results continue to show that the coefficient on Epidemic is positive and statistically significant, thus supporting earlier findings.

4.5 | Accounting for potential simultaneity between epidemics and the shadow economy

It is possible that there are reverse feedbacks from the shadow economy to epidemics—for instance, nations with a large shadow economy (since the informal sector operators do not follow health and safety regulations and are not monitored), might have a larger incidence and diffusion of epidemics.
To mitigate concerns with endogeneity, we, therefore, employ the lagged value of epidemic and re-estimate the baseline specification. The results, displayed in Model 4.3 of Table 4, show that the coefficient on lagged value of Epidemic is positive and statistically significant at conventional levels, thereby confirming our baseline results. This also suggests that the impact of epidemics on the shadow economy persists over time, which is in line with the reasoning of Jordá et al. (2020). The results for the remainder of the variables are consistent with our baseline findings.

### 4.6 Accounting for potential simultaneity between growth and the shadow economy

Economic growth is an overarching measure with potentially numerous linkages. Thus, a useful test of the validity of our findings should address the possible simultaneity between economic growth and the shadow economy that might bias our results. A large shadow economy might promote growth and development by, for example, providing complementary goods and services (e.g., sub-contracting) or it might deter growth by undermining the government’s ability to collect tax revenues that are used to finance growth-supporting public goods (see Goel et al., 2019; Schneider & Enste, 2000 for a discussion). Furthermore, most of the other control variables could have a relation with economic growth.

To alleviate issues with reverse causality between economic growth and the shadow economy, we re-estimate the baseline model without the control variable ECgrowth and present the corresponding results in Model 4.4 of Table 4. The coefficient on Epidemic remains positive and statistically significant, thereby instilling confidence in our findings—again, as hypothesized, epidemics feed the informal sector.

### 4.7 Accounting for heterogeneous effects related to income and geography

In spite of the different controls that we employ to capture cross-country variations, it is possible that some of the structural and institutional differences cannot be readily quantified. As a result, we consider different samples of nations to shed additional light on the results—see Table A1 for each sub-sample of countries. To this end, we split the sample of countries into non-OECD and OECD countries. In addition, we account for the unique geography of non-island relative to island nations. Island nations have natural barriers against the spread of epidemics from other nations, and they are also somewhat insulated from shadow economy spillovers from neighboring nations (Goel & Saunoris, 2014). On the other hand, the OECD group of nations is quite prosperous and has strengthened institutions, which might help fight epidemics and control the shadow economy as well. In our overall sample of 126 nations, there were 107 non-island nations and 37 OECD nations.

The results, replicating the baseline model from Table 2, are presented in Table 5. We find that the emergence of an epidemic is positively associated with the size of the shadow economy in non-island nations (Model 5.1) and the magnitude is very similar to the baseline results. This suggests that non-island nations are similar to the overall sample—there remains a positive influence of epidemics on the prevalence of the shadow economy. Similarly, island nations (Model 5.2) show a positive and statistically significant influence from the incidence of epidemics on the shadow economy; however, the magnitude is almost half compared to non-island nations. This could be because there is relatively better monitoring of informal activities, fewer informal sector opportunities, or a lack of spillovers from immediate neighbors in such nations. There might also be better information flows about virus mitigation and containment in nations that are not isolated.

The impacts of epidemics are similar for non-OECD countries (Model 5.3) and OECD countries (Model 5.4). That is, the coefficient on Epidemic is positive and statistically significant and the magnitude is of similar size to the baseline findings. However, we find interesting differences in the two samples across the control variables. For instance, the coefficient on PolFreedom is negative and statistically significant for OECD countries, while economic growth negatively effects shadow in non-OECD countries, but not OECD countries.

### 4.8 Additional robustness results

We conduct three additional robustness analyses to check the sensitivity of the baseline results and report these findings in Table 6. First, we control for country-specific time trends and present the results in Model 6.1. These findings show
that the coefficient on Epidemic maintains its statistical significance albeit is smaller in magnitude relative to the baseline results in Model 2.1. The coefficients on the control variables are similar to the baseline results, with the exception that the coefficient on government size is positive and highly statistically significant. This is consistent with the notion that a larger government increases the size of the shadow economy.

Second, because the severity of epidemics may distort the impact of epidemics on the shadow economy, we include a control variable that accounts for the severity of epidemics, measured by the number of deaths caused by epidemics (Deaths). These results are reported in Model 6.2 of Table 6. The coefficient on Epidemic maintains its statistical significance and magnitude while the coefficient on Deaths is statistically insignificant at conventional levels. The coefficients on the rest of the control variables are similar to the baseline findings.

Finally, the shadow economy in economically free countries might respond differently to epidemics relative to economically repressed countries. For instance, in economically free countries, individuals and firms have a high degree of freedom to adjust to epidemic shocks, while in economically unfree countries with considerable regulations reduce the free adjustment of individuals and firms and encourage their migration underground. To check for the possible heterogeneous response to epidemics in economically free and unfree countries, we split the sample based on the variable economic freedom that comes from the Heritage Foundation classification of less than 60 (less free) and greater than or equal to 60 (more free) and re-estimate the baseline model. These results are reported in Models 6.3 and 6.4 in Table 6. Interestingly, the coefficient on Epidemic in economically unfree countries is positive and highly statistically significant, while it is statistically insignificant and less than half the magnitude in economically free countries. This confirms that the lack of economic freedom encourages migration underground in response to epidemics. The control variables also show slight differences. For instance, the coefficient on EcGrowth is statistically insignificant in Model 6.4, while the coefficients on Federal and EthnicINQ are statistically insignificant in Model 6.3.

In summary, the results from the robustness checks largely confirm the validity of our baseline findings that the occurrence of epidemics drives individuals and firms underground. The concluding section follows.

5 CONCLUSIONS

The current coronavirus crisis has added a sense of urgency to related effective health and economic policies (https://www.cdc.gov/coronavirus/2019‐ncov/index.html; https://www.weforum.org/covid‐action‐platform). The scale and scope of the unexpected events have challenged resources and policymakers. Academics are also trying to respond to this challenge by providing new insights, although all related data for many analyses will only emerge over time.

Whereas numerous drivers of the shadow economy have been considered in the literature (Gërshani, 2004; Goel & Nelson, 2016; Schneider & Enste, 2000), the consideration of spillovers from epidemics is new. The informal sector undermines compliance with government regulations and lowers tax collections. Our main hypothesis is that the incidence of epidemics positively impacts the spread of the shadow economy.

Using panel data for over 125 nations and nesting the empirical analysis in the broader literature on the drivers of the shadow sector, we find that the incidence of epidemics positively and significantly contributes to the spread of the underground sector. Numerically, the occurrence of an epidemic increases the size of the shadow economy (as a percentage of GDP) by 0.74 percentage points. These main findings withstand alternative considerations of possible simultaneity, outliers, subsamples of nations, different sets of controls, and regional and time effects.

The other results regarding the influence of economic and political freedoms largely support the literature. While many determinants of the underground or the shadow sector have been considered in the literature (Goel & Nelson, 2016; Schneider & Enste, 2000), the insight about spillovers from epidemics seems novel. These findings also contribute to the renewed academic interest in the economics of epidemics (Alfano & Ercolano, 2020; Baldwin & di Mauro, 2020; Berdiev & Saunoris, 2021; Beyer et al., 2021; De Wispelaere & Gillis, 2021; Farzanegan et al., 2021; Folgi & Veldkamp, 2019; Goel, Nelson, & Goel, 2021; Kumar et al., 2021; Rasul, 2020; Williams & Kayaoglu, 2020).

Whereas containment of the shadow economy is a worthwhile policy undertaking in any case (to prevent tax leakages and ensure compliance with environmental and safety regulations), our results suggest some additional policy objectives in times of epidemics (see De Wispelaere & Gillis, 2021; Williams & Kayaoglu, 2020). In particular, in the present COVID-19 era, while government efforts are primarily directed toward containment and treatment of the virus, it would behoove policymakers to pay some attention to spillovers on economic activities, such as the shadow economy. Such attention to the informal sector is important because a greater shadow economy limits government resources,
which would undermine the fight for future diseases, and the containment of current ones due to lax adherence with health and safety regulations.

With some economic sectors disproportionately adversely impacted by the pandemic and workers there transitioning to the alternative employment avenues with lower entry barriers (see Kumar et al., 2021), one could make the argument that certain shadow activities might be treated more leniently for enforcement purposes. However, such initiatives might have spillovers to other occupations and might engender longer-term inertia (see De Wispelaere & Gillis, 2021). These spillovers toward a greater shadow involvement might take different turns as the coronavirus fight enters the vaccination stage.

**ACKNOWLEDGMENTS**

We thank the editor and two anonymous referees for valuable comments and suggestions.

**ORCID**

Rajeev K. Goel [https://orcid.org/0000-0001-9580-3196](https://orcid.org/0000-0001-9580-3196)

**ENDNOTES**

1 The World Health Organization defines an epidemic as: “The occurrence in a community or region of cases of an illness, specific health-related behavior, or other health-related events clearly in excess of normal expectancy,” [https://www.who.int/hac/about/definitions/en/](https://www.who.int/hac/about/definitions/en/).

2 Specifically, CRED defines biological disasters as, “A hazard caused by the exposure to living organisms and their toxic substances (e.g. venom, mold) or vector-borne diseases that they may carry. Examples are venomous wildlife and insects, poisonous plants, and mosquitoes carrying disease-causing agents such as parasites, bacteria, or viruses (e.g., malaria),” [https://www.emdat.be/classification](https://www.emdat.be/classification).

3 It is important to note that the focus of this study is on the impact(s) of disease epidemics. Epidemics affect a particular area or population, while pandemics are a result of an epidemic diffusing across numerous nations/jurisdictions (see https://www.cdc.gov/csels/dsepd/ss1978/lesson1/section11.html). Although the results of this study are also informative for pandemics like the current coronavirus crisis, they directly relate to epidemics.

4 [https://www.bloomberg.com/news/articles/2020-05-18/rogue-businesses-go-underground-as-covid-black-market-takes-off](https://www.bloomberg.com/news/articles/2020-05-18/rogue-businesses-go-underground-as-covid-black-market-takes-off).

5 Table A3 provides a brief summary of selected papers from Section 2.

6 For examples of research that has utilized the HT estimator, see Baltagi and Khanti-Akom (1990), Dixit and Pal (2010), and Rice and Contoyannis (2001).

7 The results are robust to alternate configurations of exogenous and endogenous variables. These results are available upon request from the authors.

8 Recent developments have also included the measurement of economic activity via nighttime light intensity (see, e.g., Beyer et al., 2021).

9 We also considered, as a measure of the spread of the epidemic, the number of people (100 or over) affected, injured or homeless due to an epidemic. We replaced Epidemic with this variable (EpidemicINTENSITY—in log, per capita terms) and re-estimated the baseline model. The coefficient on this variable was positive and statistically significant, implying that, similar to epidemic incidence, epidemic intensity also increased the shadow economy. These results are available upon request.

10 We also checked the robustness of these findings by considering additional covariates including a measure of regulatory quality, population density, and exports as a percentage of GDP. These results, not reported here but available upon request, continue to support our baseline models.

11 We also considered the widely used measure of the shadow economy from Schneider et al. (2010), which is also based on the MIMIC method. These results were consistent with the baseline findings with a slightly smaller magnitude on Epidemic. These results are available upon request from the authors.

12 As an additional robustness check, we also considered the lagged value of ECgrowth in the baseline models. Re-estimating the baseline models with the lagged value of ECgrowth confirmed our main findings—these results are available upon request.

13 See also Berdiev and Saunoris (2020) for cross-country evidence of corruption spillovers to formal and informal entrepreneurship.

14 Geloso and Bologna Pavlik (2021) show that for the 1918 pandemic the effect of excess mortality is lessened by economic freedom.

**REFERENCES**

Adda, J. (2016) Economic activity and the spread of viral diseases: evidence from high frequency data. *Quarterly Journal of Economics*, 131(2), 891–941.

Alesina, A., Michalopoulos, S. & Papaioannou, E. (2016) Ethnic inequality. *Journal of Political Economy*, 124(2), 428–488.

Alfano, V. & Ercolano, S. (2020) The efficacy of lockdown against COVID-19: a cross-country panel analysis. *Applied Health Economics and Health Policy*, 18, 509–517. Available from: https://doi.org/10.1007/s40258-020-00596-3
Armien, B., Suaya, J.A., Quiroz, E., Sah, B.K., Bayard, V., Marchena, L. et al. (2008) Clinical characteristics and national economic cost of the 2005 dengue epidemic in Panama. The American Journal of Tropical Medicine and Hygiene, 79(3), 364–371.

Bajada, C. & Schneider, F. (2009) Unemployment and the shadow economy in the OECD. Revue Economique, 60(5), 1033–1067.

Baldwin, R. & Weder di Mauro, B. (Eds.) (2020) Economics in the time of COVID-19. London: CEPR Press.

Baltagi, B.H. (2008) Econometric analysis of panel data. Chichester: John Wiley & Sons.

Baltagi, B.H., Bresson, G. & Pirotte, A. (2003) Fixed effects, random effects or Hausman–Taylor? A pretest estimator. Economics Letters, 79(3), 361–369.

Baltagi, B.H. & Khanti-Akom, S. (1990) On efficient estimation with panel data: an empirical comparison of instrumental variables estimators. Journal of Applied Econometrics, 5(4), 401–406.

Barnett, V. & Lewis, T. (1994) Outliers in statistical data. Chichester: John Wiley & Sons.

Becker, C.M. (1990) The demo-economic impact of the AIDS pandemic in sub-Saharan Africa. World Development, 18(12), 1599–1619.

Baltagi, B.S. (1968) Crime and punishment: an economic approach. Journal of Political Economy, 76(2), 169–217.

Berdiev, A.N., Goel, R.K. & Saunoris, J.W. (2020) Dimensions of ethnic diversity and underground economic activity: cross-country evidence. Public Finance Review, 48(2), 178–211.

Berdiev, A.N. & Saunoris, J.W. (2018) Does globalisation affect the shadow economy? The World Economy, 41(1), 222–241.

Berdiev, A.N. & Saunoris, J.W. (2020) Cross-country evidence of corruption spillovers to formal and informal entrepreneurship. Contemporary Economic Policy, 38(1), 48–66.

Berdiev, A.N. & Saunoris, J.W. (2021) Do disease epidemics stimulate or repress entrepreneurial activity? Eastern Economic Journal, 47(4), 464–486. Available from: https://doi.org/10.1080/01455195.2021.1959498

Berdiev, A.N., Saunoris, J.W. & Schneider, F. (2018) Give me liberty, or I will produce underground: effects of economic freedom on the shadow economy. Southern Economic Journal, 85(2), 537–562.

Beyer, R.C.M., Franco-Bedoya, S. & Galdo, V. (2021) Examining the economic impact of COVID-19 in India through daily electricity consumption and nighttime light intensity. World Development, 140, 105287.

Bloom, D.E. & Mahal, A.S. (1997) Does the AIDS epidemic threaten economic growth? Journal of Econometrics, 77(1), 105–124.

Breusch, T.S., Mizon, G.E. & Schmidt, P. (1989) Efficient estimation using panel data. Econometrica, 57(3), 695–700.

Cagan, P. (1958) The demand for currency relative to the total money supply. Journal of Political Economy, 66(4), 303–328.

Dau, L.A. & Cuervo-Cazurra, A. (2014) To formalize or not to formalize: entrepreneurship and pro-market institutions. Journal of Business Venturing, 29(5), 668–686.

De Wispelaere, F. & Gillis, D. (2021) COVID-19 and the fight against undeclared work: lessons learned and to be learned. Working Paper, KU Leuven. Available at: https://hiva.kuleuven.be/nl/nieuws/docs/hiva-discussion-paper-de-wispelaere-gillis.pdf

Dell’Anno, R. & Solomon, O.H. (2008) Shadow economy and unemployment rate in USA: is there a structural relationship? An empirical analysis. Applied Economics, 40(19), 2537–2555.

Dell’Anno, R. & Teobaldelli, D. (2015) Keeping both corruption and the shadow economy in check: the role of decentralization. International Tax and Public Finance, 22(1), 1–40.

Dixit, K. & Pal, R. (2010) The impact of group incentives on performance of small firms: Hausman–Taylor estimates. Managerial and Decision Economics, 31(6), 403–414.

Dreher, A., Kotsogiannis, C. & McCrorist, S. (2009) How do institutions affect corruption and the shadow economy? International Tax and Public Finance, 16(6), 773–796.

Elgin, C. (2012) Cyclicality of shadow economy. Economic Papers, 31(4), 478–490.

Farzanegan, M.R., Feizi, M. & Gholipour, H.F. (2021) Globalization and the outbreak of COVID-19: an empirical analysis. Journal of Risk and Financial Management, 14(3), 1–10.

Folgi, A. & Veldkamp, L. (2019) Germs, social networks and growth. The Review of Economic Studies. forthcoming. Available at: https://www.researchgate.net/publication/336297926_Germs_social_networks_and_growth/

Geloso, V. & Bologna Pavlik, J. (2021) Economic freedom and the economic consequences of the 1918 pandemic. Contemporary Economic Policy, 39(2), 255–263.

Gërxhani, K. (2004) The informal sector in developed and less developed countries: a literature survey. Public Choice, 120(3–4), 267–300.

Goel, R.K. (1990) The substitutability of capital, labor, and R&D in U.S. Manufacturing. Bulletin of Economic Research, 42(3), 211–227.

Goel, R.K. & Haruna, S. (2021) Unmasking the demand for masks: analytics of mandating coronavirus masks. Metroeconomica, 72(3), 580–591.

Goel, R.K., Mazhar, U. & Saunoris, J.W. (2021) Identifying the corrupt cog in the wheel: dimensions of supply chain logistics and cross-country corruption. Australian Economic Papers, forthcoming. Available from: https://doi.org/10.1111/1467-8454.12226

Goel, R.K. & Nelson, M.A. (2016) Shining a light on the shadows: identifying robust determinants of the shadow economy. Economic Modelling, 58, 351–364.

Goel, R.K., Nelson, M.A. & Goel, V.Y. (2021) COVID-19 vaccine rollout—scale and speed carry different implications for corruption. Journal of Policy Modeling, 43, 503–520. Available from: https://doi.org/10.1016/j.jpolmod.2021.04.003

Goel, R.K., Ram, R., Schneider, F. & Potempa, A. (2020) International movements of money and men: impact on the informal economy. Journal of Economics and Finance, 44(1), 179–197.

Goel, R.K., Saunoris, J.W. (2014) Global corruption and the shadow economy: spatial aspects. Public Choice, 161(1–2), 119–139. Available from: https://doi.org/10.1007/s11127-013-0135-1
Goel, R.K., Saunoris, J.W. & Schneider, F. (2019) Growth in the shadows: effect of the shadow economy on U.S. economic growth over more than a century. Contemporary Economic Policy, 37(1), 50–67.

Halasa, Y.A., Shepard, D.S. & Zeng, W. (2012) Economic cost of dengue in Puerto Rico. The American Journal of Tropical Medicine and Hygiene, 86(5), 745–752.

Hausman, J.A. & Taylor, W.E. (1981) Panel data and unobservable individual effects. Econometrica, 49(6), 1377–1398.

Jordà, O., Singh, S.R. & Taylor, A.M. (2020) Longer-run economic consequences of pandemics. National Bureau of Economic Research Working Paper # 26934.

Kahn, M.E. (2005) The death toll from natural disasters: the role of income, geography, and institutions. The Review of Economics and Statistics, 87(2), 271–284.

Kaufmann, D. & Kaliberda, A. (1996) Integrating the unofficial economy into the dynamics of post-socialist economies. A framework of analysis and evidence. Policy Research Working Paper 1691. The World Bank.

Kaufmann, D., Kraay, A. & Mastruzzi, M. (2010) The worldwide governance indicators: methodology and analytical issues. Policy Research Working Paper 5430. The World Bank.

Kumar, A., Priya, B. & Srivastava, S.K. (2021) Response to the COVID-19: understanding implications of government lockdown policies. Journal of Policy Modeling, 43(1), 76–94.

Loayza, N.V., Servén, L. & Sugawara, N. (2009) Informality in Latin America and the Caribbean. Policy Research Working Paper 4888. The World Bank.

Ma, C., Rogers J.H. & Zhou, S. (2020) Global economic and financial effects of 21st century pandemics and epidemics. SSRN Electronic Journal. Available from: https://doi.org/10.2139/ssrn.3565046

Medina, L. & Schneider, F. (2019) Shedding light on the shadow economy: a global database and the interaction with the official one. CESifo Working Paper. No. 7981.

Noy, I. (2009) The macroeconomic consequences of disasters. Journal of Development Economics, 88(2), 221–231.

Prior, I. & Stanhope, J. (1980) Epidemics, health and disease in a small, isolated environment. World Development, 8(12), 995–1013.

Raddatz, C. (2007) Are external shocks responsible for the instability of output in low-income countries? Journal of Development Economics, 84(1), 155–187.

Rasul, I. (2020) The economics of viral outbreaks. American Economic Review, AEA Papers and Proceedings, 110, 265–268.

Rice, N. & Contoyannis, P. (2001) The impact of health on wages: evidence from the British Household panel survey. Empirical Economics, 26(4), 599–622.

Schneider, F. (2010) The influence of public institutions on the shadow economy: an empirical investigation for OECD countries. Review of Law & Economics, 6(3), 441–468.

Schneider, F. & Buehn, A. (2013) Estimating the size of the shadow economy: methods, problems and open questions. CESifo Working Paper Series No. 4448.

Schneider, F., Buehn, A. & Montenegro, C. (2010) New estimates for the shadow economies all over the world. International Economic Journal, 24, 443–461.

Schneider, F. & Enste, D.H. (2000) Shadow economies: size, causes, and consequences. Journal of Economic Literature, 38(1), 77–114.

Schneider, F. & Enste, D.H. (2013) The shadow economy: an international survey. Cambridge, MA: Cambridge University Press.

Tanzi, V. (1983) The underground economy in the United States: annual estimates, 1930-80. International Monetary Fund Staff Papers, 30(2), 283–305.

The Heritage Foundation. (2017) Index of economic freedom. Available at: https://www.heritage.org

Tirolo, J. (1999) Incomplete contracts: where do we stand? Econometrica, 67(4), 741–781. Tirolo, 1999.

Tirolo, J. (2009) Cognition and incomplete contracts. American Economic Review, 99(1), 265–294. Available from: https://doi.org/10.1257/aer.99.1.265

Torgler, B. & Schneider, F. (2009) The impact of tax morale and institutional quality on the shadow economy. Journal of Economic Psychology, 30(2), 228–245.

Treisman, D. (2002) Defining and measuring decentralization: a global perspective. Unpublished manuscript. Available at: https://www.sscnet.ucla.edu/polisci/faculty/treisman/Papers/defin.pdf

Williams, C.C. & Kayaoglu, A. (2020) The Coronavirus pandemic and Europe's undeclared economy: impacts and a policy proposal. South East European Journal of Economics and Business, 15(1), 80–92.

Wooldridge, J.M. (2002) Econometric analysis of cross-section and panel data. Cambridge, MA: MIT Press.

World Bank. (2018) World development indicators. Washington, DC: The World Bank.

**SUPPORTING INFORMATION**

Additional supporting information may be found in the online version of the article at the publisher's website.

---

**How to cite this article:** Berdiev, A.N., Goel, R.K. & Saunoris, J.W. (2022) Do disease epidemics force economic activity underground? International evidence. Contemporary Economic Policy, 40(2), 263–282. Available from: https://doi.org/10.1111/coep.12557
### APPENDIX A

**TABLE A1  Countries used in the analysis**

| Country                  | Dominican Republic\(^a\) | Korea, Rep.* | Portugal* |
|--------------------------|---------------------------|--------------|-----------|
| Albania                  |                           | Korea, Rep.* | Portugal* |
| Algeria                  | Ecuador                   | Latvia*      | Romania   |
| Angola                   | Egypt, Arab Rep.          | Korea, Rep.* | Russian Federation |
| Argentina                | El Salvador               | Lebanon*     | Saudi Arabia |
| Armenia                  | Estonia*                  | Liberia*     | Senegal   |
| Australia*               | Ethiopia                  | Libya*       | Sierra Leone |
| Austria*                 | Finland*                  | Lithuania*   | Singapore^ |
| Azerbaijan               | France*                   | Luxembourg*  | Slovak Republic* |
| Bahamas, The^\(^a\)      | Gabon                     | Madagascar^  | Slovenia* |
| Bahrain^                 | Gambia, The               | Malawi       | South Africa |
| Bangladesh               | Germany*                  | Malaysia     | Spain*    |
| Belarus                  | Ghana                     | Mali         | Sri Lanka^ |
| Belgium*                 | Greece*                   | Malta*       | Suriname  |
| Bolivia                  | Guatemala                 | Mexico*      | Sweden*   |
| Botswana                 | Guinea                    | Moldova      | Switzerland^ |
| Brazil                   | Guinea-Bissau             | Mongolia     | Tanzania  |
| Brunei Darussalam^       | Guyana                    | Morocco      | Thailand  |
| Bulgaria                 | Haiti^                    | Mozambique   | Togo      |
| Burkina Faso             | Honduras                  | Namibia      | Tunisia   |
| Cameroon                 | Hungary*                  | Netherlands* | Turkey*   |
| Canada*                  | Iceland^\(^a\)            | New Zealand^\(^a\) | Uganda |
| Chile*                   | India                     | Nicaragua    | Ukraine   |
| China                    | Indonesia^                | Niger        | United Arab Emirates |
| Colombia*                | Iran, Islamic Rep.        | Nigeria      | United Kingdom^\(^a\)* |
| Congo, Dem. Rep.         | Ireland^\(^a\)            | Norway*      | United States* |
| Congo, Rep.              | Israel*                   | Oman         | Uruguay   |
| Costa Rica               | Italy*                    | Pakistan     | Venezuela, RB |
| Cote d’Ivoire            | Jamaica^                  | Papua New Guinea^\(^a\) | Vietnam |
| Croatia                  | Japan^\(^a\)*             | Paraguay     | Zambia    |
| Cyprus^                  | Jordan                    | Peru         | Zimbabwe  |
| Czech Republic*          | Kazakhstan                | Philippines^ |           |
| Denmark*                 | Kenya                     | Poland*      |           |

**Note:** $N = 126.$

* denotes OECD countries (37).

^ denotes island countries (19).
The incidence of epidemics positively contributes to the spread of the underground sector.

The unemployed individuals from the official sector have a higher propensity to enter the informal sector.

Counter-cyclical relationship between shadow economies and formal sector business cycles.

Positive relationship between the overall globalization index and coronavirus case death rates.

The incidence of disasters that also encompasses epidemics lowers formal economic activity.

Nations that have imposed lockdowns on operations experienced lower new coronavirus cases.

The underground economy provides refuge for individuals who lose formal sector employment.

Negative relationship between new coronavirus cases and lockdowns and economic operations.
**FIGURE A1** The number of epidemics from 1995 to 2017. *Source: www.cred.be and authors' calculations [Colour figure can be viewed at wileyonlinelibrary.com]*

**FIGURE B1** The average size of the shadow economy (percent of GDP) from 1995 to 2017. *Source: Medina and Schneider (2019) and authors' calculations [Colour figure can be viewed at wileyonlinelibrary.com]*