Effectiveness of Penalties for Lockdown Violations During the COVID-19 Pandemic in Germany

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Objectives. To investigate whether the imposition of fines can mitigate the spread of COVID-19.

Methods. We used quasi-experimental difference-in-difference models. On March 20, 2020, Bavaria introduced fines as high as €25 000 (US $28 186) against citizens in violation of the *Bundesland's* (federal state's) lockdown policy. Its neighboring *Bundesländer* (federal states), on the other hand, were slow to impose such clear restrictions. By comparing 38 *Landkreise* (counties) alongside Bavaria's border from March 15 to May 11 using data from the Robert Koch Institute, we produced for each *Landkreis* its (1) time-dependent reproduction numbers (R_t) and (2) growth rates in confirmed cases.

Results. The demographics of the *Landkreise* were similar enough to allow for difference-in-difference analyses. *Landkreise* that introduced fines on March 20 reduced the R_t by a further 0.32 (95% confidence interval [CI] = –0.46, –0.18; $P < .001$) and decreased the growth rate in confirmed cases by an additional 6 percentage points (95% CI = –0.11, –0.02; $P = .005$) compared with the control group.

Conclusions. Imposing fines may slow down the spread of COVID-19.

Public Health Implications. Lockdowns may work better when governments introduce penalties against those who ignore them. (*Am J Public Health.* 2020;110:1844–1849. https://doi.org/10.2105/AJPH.2020.305903)

See also Drabo et al., p. 1724.

Coronavirus disease 2019 (COVID-19) has been rapidly spreading around the globe, becoming a pandemic affecting many countries worldwide.[1] By July 8, 2020, the number of infections had exceeded 11 million cases worldwide, and the European region alone saw more than 201 000 deaths.[2] To respond to COVID-19, many countries have been using a combination of containment and mitigation strategies aimed at decreasing the surge of COVID-19 patients. Most national response strategies include varying levels of contact tracing, self-isolation, or household quarantine,[3] as well as the promotion of public health measures such as handwashing and social distancing.[4]

In the public health literature, theoretical models posit that government interventions such as school closure, workplace distancing,[5] and quarantine could reduce the number of infections.[6] However, even as Sen et al. empirically illustrated that staying at home could reduce the spread of an exponentially spreading virus,[3] there is still no direct evidence that quarantines can prevent the spread of COVID-19.[6] As a result of such uncertainty, there is currently a great deal of variation in each nation's enforcement of interventions. In the case of lockdowns, the governments of South Africa and the Philippines have even pointed guns at their own citizens,[7,8] whereas countries such as the United Kingdom had—until recently—been restricting their enforcement measures to relatively small fines (up to £120).[9]

The German *Bundesland* (federal state) of Bavaria and its neighboring *Bundesländer* (federal states; Baden Württemberg, Hessen, Thüringen, and Saachen) allow us to empirically assess the effects of financial penalties by using a quasi-experimental difference-in-difference design. On March 20, 2020, Bavaria imposed a strict lockdown, allowing people to leave their homes only for necessities, such as going to work or to the doctor. Violating the decree could result in a fine as high as €25 000 (US $28 186).[10]

By contrast, Bavaria's neighbors have been slow to introduce such strict measures against their citizens' public lives. Although the German federal government issued a 9-point measure against the spread of COVID-19 on March 22, no provisions were immediately made for punishing citizens who ignored these guidelines.[11] Moreover, while Bavaria's neighbors eventually followed suit, it took as much as a further 53 days (for example in Thüringen) for these *Bundesländer* to introduce fines. Meanwhile, other forms of government intervention (such as the closure of schools, shops, bars, and sports venues, as well as the mandatory wearing of masks) simultaneously affected both Bavaria and its neighboring *Bundesländer*. Therefore, the pronounced difference between the policy of Bavaria and that of its neighbors allows for a difference-in-difference analysis among *Landkreise* (counties) alongside the Bavarian border.

METHODS

Using data from the Robert Koch Institute's COVID-19 dashboard (retrieved on

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June 2, 2020), we derived the time-dependent reproduction number and the growth rate in cumulative confirmed cases in each of the 38 *Landkreise* situated along the Bavarian border from March 15 to May 11, 2020 (Figure 1).[12] Our data set uses a panel design, in which the number of confirmed cases are recorded daily at the *Landkreis* level. The data set includes the following variables: *Bundesland*, *Landkreis*, date, treatment group, treatment period, the time-dependent reproduction number, and the growth rate in cumulative confirmed cases. Because all the *Bundesländer* in the sample eventually introduced fines from May 12 onward, we limited our observation period to May 11. In addition, we discarded data from early March, because their data collection mechanism (manual) differed from that of later periods (electronic transmission). Throughout our period of observation, the Robert Koch Institute consistently used laboratory-confirmed cases to determine COVID-19 cases. Variations in the total number of tests conducted did not seem to affect our dependent variables of interest.[13]

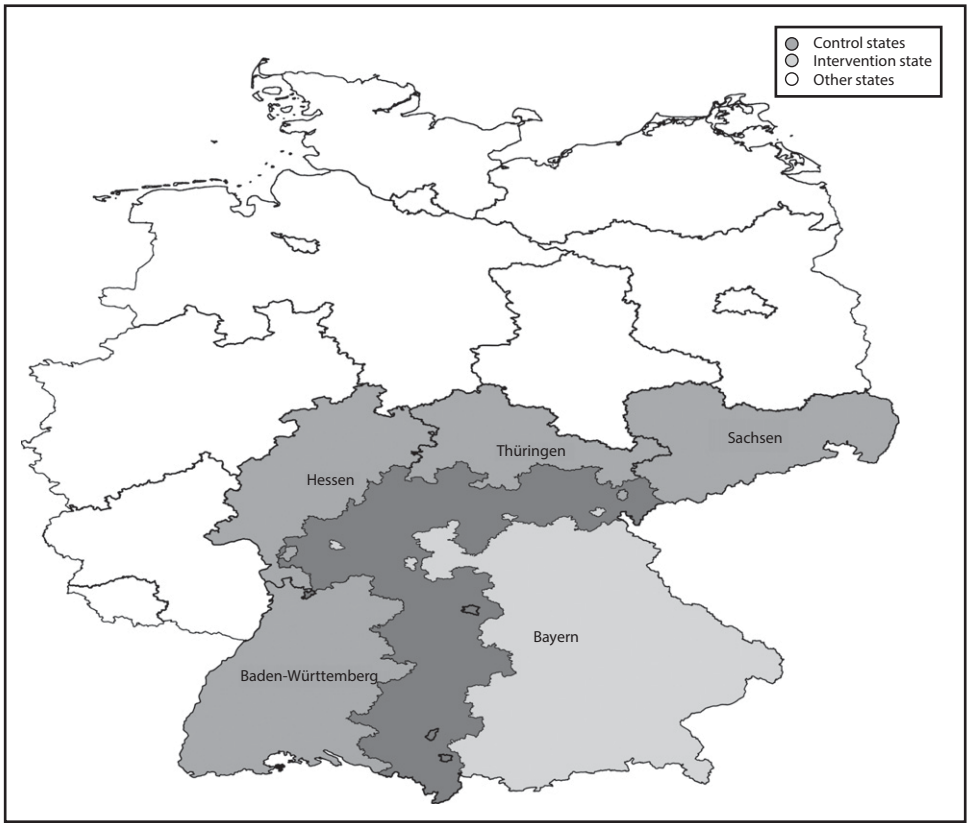
Five *Landkreise* (Ansbach, Dillingen, Hildburghausen, Sonneburg, and Vogtlandkreis) had missing data, because these *Landkreise* had no confirmed cases at the beginning of the studied period. Two of these were from the treatment group and 3 were from the control group. We conducted sensitivity analysis to assess whether these cases affected our findings.

Penalties Against Violators

All *Landkreise* under the administrative district of Bavaria introduced penalties against lockdown violations on March 20. Because Germany is a federal republic, each *Landkreis* is subject to its respective *Bundesland*'s administrative control. Of the 5 *Bundesländer* alongside the Bavarian border (Bavaria, Baden Württemberg, Hessen, Thüringen, and Saachen; Figure 1) only Bavaria started imposing a maximum fine of €25 000 (US $28 186) on March 20. Using this definition, we identified 19 *Landkreise* as the treatment group (introduced penalties on March 20) and the other 19 as the control group (Appendix, Section 1, available as a supplement to the online version of this article at http://www.ajph.org).

Time-Dependent Reproduction Number

The time-dependent reproduction number, R_t, is defined as the number of secondary infections that arose from a typical primary case in a completely susceptible population.[14] The magnitude of R_t is a useful indicator of both the risk of an epidemic and the effect of an intervention.[14] In our study, we used time-dependent reproduction numbers



Note. The shaded area in the map indicates the 38 *Landkreise* located along the Bavarian border that were included in our study. *Landkreise* in Bayern (Bavaria) imposed fines on March 20, 2020, while the other *Landkreise* did not.

FIGURE 1—German *Landkreise* (Counties) Alongside Bavaria's Border That Were Included in the Difference-in-Difference Analysis: Germany, March 15–May 11, 2020

proposed by Wallinga and Teunis.[15] The computation produces the reproduction number over time; this way, the effects of a government intervention can be measured as changes in R_t. We derived the R_t from the Robert Koch Institute's cumulative patient data by using the "R0" package in R software version 3.6.2 (R Core Team, Vienna, Austria; Appendix, Section 3).[16]

Growth in Confirmed Cases

In addition to the time-dependent reproduction number, we measured the growth in confirmed cases as the rate at which the number of cumulative confirmed cases in each *Landkreis* was rising compared with the day before (Appendix, Section 3). The growth in the cumulative number of patients is often used as a marker of infectivity as well as a measure of prevention.[17,18] For this reason, we used $\frac{y_t}{y_{t-1}} - 1$ (where y_t denotes the cumulative number of patients at time t) to provide more easily interpretable results indicating the effect of financial penalties.

Statistical Analysis

We used quasi-experimental difference-in-difference models to estimate the impact of financial penalties. Similar methods have been used in previous research concerning the health effects of various policies.[19–21] Because the bordering *Landkreise* were alike in many relevant respects—such as their demographic composition and their pretreatment trajectories in the dependent variables—we could regard the assignment of the treatment as near-random.

To estimate the effect of strict penalties on the R_t, we conducted linear ordinary least squares regressions with 1 interaction term between the treatment group (Bavaria) and the treatment period (since March 20). Our second dependent variable is the growth rate of cumulative confirmed cases. Because the number of patients increases exponentially without the provision of interventions, often more important for analyzing epidemics is the daily growth rate of infections.[17,22] Because the effect of an intervention would materialize only after the disease's incubation period, we lagged all treatment period variables by 4, 5, and 6 days, which amounts to a standard deviation around the median serial interval of COVID-19 infections.[23] In addition, we introduced fixed effects in case there were any variations at the *Landkreis* level unaccounted by the difference-in-difference models.

Although a number of health policies other than fines were introduced in Germany, major interventions simultaneously affected both the treatment and control groups. In addition, while even non-Bavarian *Bundesländer* did eventually introduce specific fines for violating lockdown restrictions, our models can estimate the difference Bavaria's early adoption of fines made for the periods in which each non-Bavarian *Bundesland* had not yet introduced the fines. See Appendix, Section 1, for a timeline of nonpharmaceutical interventions during the observed period.

For a formal description of the statistical designs, see Appendix, Section 3. We report the effects of introducing penalties in terms of absolute changes to the outcome variables. We conducted statistical analyses with Stata software version 15.0 (StataCorp LP, College Station, TX).

Parallel Trends Assumption

Central to the difference-in-difference research design is the parallel trend assumption. We assessed the validity of this assumption in 3 ways. First, using the German federal statistics data, we confirmed that the demographic attributes of the *Landkreise* alongside Bavaria's border with Baden Württemberg, Hessen, Thüringen, and Saachen were sufficiently similar with each other to allow for difference-in-difference analyses.[24] Second, using ordinary least squares regressions, we found that the outcome variables' change over time was no different in the treatment group than it was in the control group (Appendix, Section 4). Finally, a placebo test between Hessen and its neighboring Nordrhein-Westfalen (a "fake" treatment group) produced zero coefficients (Appendix, Section 4).

Sensitivity Analysis

We conducted several sensitivity analyses. First, we tested whether an R_t concerning only the most vulnerable population (aged older than 60 years) would yield different results. In addition, we tried excluding any observations that could have potentially exaggerated the results of our analyses. Finally, we noticed that 5 of the *Landkreise* had missing values in the pretreatment period. Because the missing values could have affected the pretreatment average of the dependent variables, we tested whether substituting these values with zeros made any difference.

RESULTS

For most of the baseline observations, the mean values were no different in Bavarian *Landkreise* than other *Landkreise* in the sample (Appendix, Section 4). Cumulative COVID-19 cases (as percentage of population), the baseline R_0, the baseline growth rate, the proportion of citizens aged 60 years or older, and the proportion of male citizens were the same regardless of whether a *Landkreis* was part of Bavaria or not ($P > .10$).[24] By contrast, in some areas, the 2 groups were significantly different. The size of

TABLE 1—Changes to the Time-Dependent Reproduction Number (R_t) and the Growth Rate of Cumulative Cases in *Landkreise* (Counties) on Either Side of the Bavarian Border After Bavaria Introduced Financial Penalties Against Lockdown Violations: Germany, March 15–May 11, 2020

Treatment Lag	DiD Estimate (95% CI)
Reproduction number	
Model 1	
4 d	−0.32 (−0.46, −0.18)
5 d	−0.32 (−0.45, −0.18)
6 d	−0.29 (−0.42, −0.16)
Model 2[a]	
4 d	−0.33 (−0.47, −0.19)
5 d	−0.32 (−0.45, −0.19)
6 d	−0.30 (−0.42, −0.17)
Growth in cases	
Model 1	
4 d	−0.06 (−0.11, −0.02)
5 d	−0.05 (−0.09, −0.00)
6 d	−0.05 (−0.09, −0.01)
Model 2[a]	
4 d	−0.07 (−0.11, −0.02)
5 d	−0.05 (−0.09, −0.01)
6 d	−0.05 (−0.09, −0.01)

Note. CI = confidence interval; DiD = difference-in-difference. Bavaria introduced financial penalties on March 20.

[a]Models with fixed effects at the *Landkreis* (county) level.

each *Landkreis*'s total population was, on average, larger in the *Landkreise* neighboring Bavaria.[24] Moreover, the proportion of unemployed citizens[25] and citizens receiving basic social security payments were greater in non-Bavarian *Landkreise* than their Bavarian counterparts.

Our analysis of these 38 *Landkreise* showed statistically significant results for both of our dependent variables. The treatment variable reduced both (1) the time-dependent reproduction number, R_t, and (2) the rate of growth in confirmed cases.

Time-Dependent Reproduction Number

Our analysis indicated that introducing financial penalties significantly reduced the time-dependent reproduction number (R_t). According to our difference-in-difference analyses, introducing financial penalties reduced the R_t by 0.32 (95% confidence interval [CI] = –0.46, –0.18; $P < .001$; Table 1 and Figure 2a).

Growth in Confirmed Cases

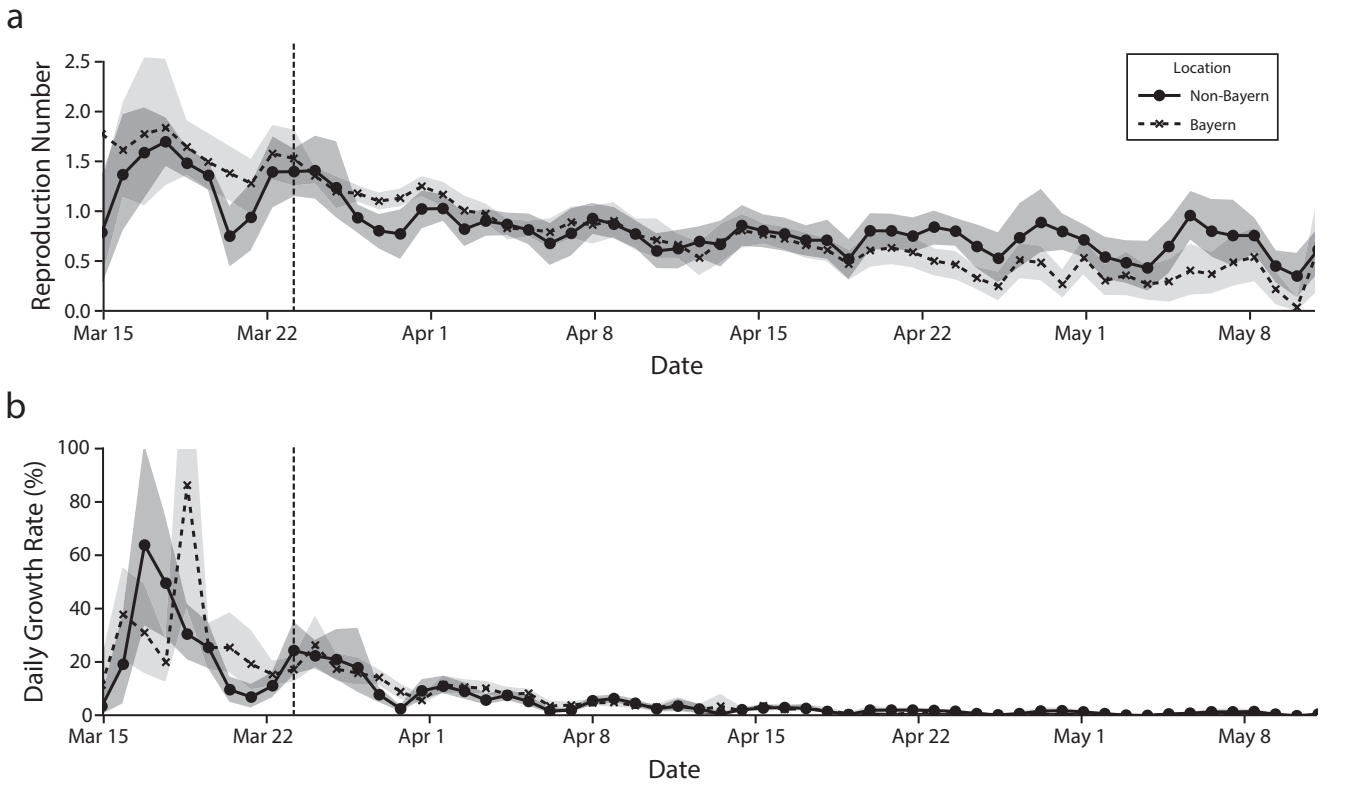
We also found that introducing penalties resulted in a –0.06 (95% CI = –0.1, –0.02; $P = .005$) difference for the growth in confirmed cases. In other words, the growth rate fell by a further 6 percentage points for *Landkreise* that introduced penalties (Table 1; Figure 2b).

Sensitivity Analyses

In general, the results of the sensitivity analyses did not contradict those of our original findings. Even when we excluded *Landkreise* with high pretreatment growths in confirmed cases or unusually high pretreatment values of R_t, the models yielded significant and substantial effects. Replacing missing values in the pretreatment period with zeros also made little difference (Table 2). On the other hand, using the alternative reproduction number resulted in null findings (see Appendix, Section 5, for further discussion).

DISCUSSION

COVID-19 is affecting the lives of many. More than 11 million people have been infected globally. At the same time, government lockdowns have been closing down factories and shops, bringing economies to a halt. To bring the SARS-CoV-2 virus under control, we need measures that work. In this light, our study offers a glimpse into how government interventions could reduce the spread of the disease. Imposing



Note. Dashed line = implementation of the intervention on March 20, 2020 (lagged by 4 d); band = 95% confidence intervals. Data shown in part a are the means of daily R_t for each group. Whereas R_t decreased in Bavarian counties, the graph illustrates a rather wax-and-wane pattern in the non-Bavarian areas. Part b shows the means of the daily growth rate in confirmed cases. The growth rate before the intervention was higher than the postintervention level in both groups.

FIGURE 2—Daily Trends of the Time-Dependent Reproduction Number (R_t) and the Growth Rate of Cumulative Cases in Bavarian and Non-Bavarian *Landkreise* (Counties) Before and After Bavaria Introduced Financial Penalties Against Lockdown Violations: Germany, March 15–May 11, 2020

TABLE 2—Sensitivity Analyses Upon German *Landkreise* (Counties) Alongside Bavaria's Border Before and After Bavaria Introduced Financial Penalties Against Lockdown Violations: Germany, March 15–May 11, 2020

Dependent Variable	Treatment Lag	DiD (95% CI)
Reproduction number		
Age ≥ 60 y	4 d	−0.03 (−0.21, 0.15)
Model 1[a]	4 d	−0.19 (−0.32, −0.06
Model 2[b]	4 d	−0.42 (−0.56, −0.28)
Growth rate		
Model 1[a]	4 d	−0.09 (−0.12, −0.06)
Model 2[b]	4 d	−0.08 (−0.13, −0.04)

Notes. CI = confidence interval; DiD = difference-in-difference. Bavaria introduced financial penalties on March 20.

[a]Models excluding anomalous cases (Biberach, Darmstadt-Dieburg, Odenwaldkreis, Schmalkalden-Meiningen, Schwabisch Hall, and Vogtlandkreis).

[b]Models replacing missing values with zero.

heavy fines for violating a lockdown has resulted in a further 0.32 decrease in the R_t, or an additional 6-percentage-point fall in the growth rate of confirmed cases.

For the first time, to our knowledge, in the field, our models present quasi-experimental empirical evidence about the effects of a nonpharmaceutical intervention implemented in response to COVID-19. In our models, we compared the time trends of the treatment and control groups. The treatment group, Bavaria, started imposing heavy fines on March 20 against people who violated the lockdown policy. The control group, on the other hand, was slow to impose strong penalties on these violators. Through the difference-in-difference models, we could examine the difference in the changes that occurred in each of these groups. In the 2 groups, the R_t was falling both before and after the policy was in effect. However, the R_t diminished more in Bavarian *Landkreise* compared with the control group. If we accept the parallel trends assumption, the control group here is equivalent to the counterfactual Bavarian *Landkreise* had Bavaria not introduced financial penalties on March 20. In other words, the difference in the changes that Bavaria and its neighboring *Landkreise* experienced throughout the period we studied is equivalent to the difference the early implementation of fines made for Bavaria.

As mentioned previously, the R_t was falling in both groups before the intervention. We suspect that this is because of other interventions in effect across the whole of Germany, including the travel restrictions across German borders, as well as social distancing measures such as the closure of schools, shops, and bars. Even so, through the difference-in-difference analysis, we were able to identify significant and substantial effects that financial penalties can have on slowing down infections. This is because we can assume that neighboring *Landkreise* are similar enough with each other in other respects, such as their susceptibility to Germany's nationwide interventions.

It was interesting that when we used an alternative R_t concerning only the elderly population as the dependent variable, the treatment had no effect. We suspect that this is because of the elderly population's characteristic lack of mobility.

Comparison With Other Studies

The results of our quasi-experimental research demonstrate how lockdown policies may be more effective when they are enforced with fines. In simulation studies about the effect of nonpharmaceutical interventions,[26] household quarantine is the most effective intervention in terms of the decrease in the peak number of cases and the delay in the outbreak peak. However, because a simulation study assumes that the intervention can persist throughout the observational period, the resulting outcomes (such as the delay in outbreak peak and the peak number of cases) cannot be compared with the outcomes of our study. On the empirical side, Sen et al. associated the number of COVID-19 cases with the timing of stay-at-home policies. Although there was no control group and no other factors were considered in this study, their conclusion is comparable to ours.[3]

Limitations

Our research is not without its limitations. While *Landkreise* in the control group did not impose penalties right away, they did introduce fines at later points in time. Moreover, Germany as a whole did declare stronger social distancing measures (on March 22) and later made it mandatory for citizens to wear masks in public. These developments may have created a negative bias for the control group during the treatment period. Nonetheless, as it took as long as a further 53 days for the control group to introduce fines, our models could still capture the effect of Bavaria introducing fines at an earlier point in time. Moreover, even if we were to believe that the posttreatment interventions had an effect on the outcome variables, it would only mean that our analysis passed an even harder test. Because the posttreatment public health measures would have reduced the difference between groups, it would mean that the real effect of lockdown penalties is greater than what our models predict.

Also, it goes without saying that financial penalties are not a cure-all. The penalties themselves could neither cure COVID-19 nor prevent further infections. At best they could only provide citizens with further incentives to abide by the lockdown regulations. Be that as it may, until a functional vaccine is developed, strong interventions such as the imposition of fines could help governments mitigate and contain the spread of the virus.

Conclusions and Public Health Implications

In sum, penalties against social distancing violations have a meaningful effect on slowing down the spread of COVID-19. Exploiting the policy difference among the 38 *Landkreise* alongside the Bavarian border, we found that, when lockdowns were strictly enforced with heavy fines, both the time-dependent reproduction number and the growth rate of confirmed cases fell significantly. These findings suggest that lockdowns, when accompanied by fines, might assist in mitigating the spread of COVID-19.

Our study may have substantial implications for policymakers. First, if many top government officials around the world had at some point questioned the efficacy of lockdowns,[27,28] our results indicate why some of the lockdown policies may have not appeared to be very effective. When citizens ignore government guidelines, decision-makers may

need to step up to make lockdown measures binding.

Second, our findings illustrate for the first time, to our knowledge, the possibility of quasi-experimentally testing the effect of government interventions on the spread of COVID-19. With good data and novel research designs, the academic community could provide the evidence upon which policies can be formed. As these studies become more readily available, policymakers should base their decisions on such empirical research.

Finally, detailed and accurate data were critical for our research. Our analysis was possible thanks to the Robert Koch Institute's data set on *Landkreis*-level daily data on confirmed COVID-19 cases. We strongly urge that states and international organizations continue to provide such detailed data for academic research. AJPH

CONTRIBUTORS

Both authors contributed equally.

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CONFLICTS OF INTEREST

The authors have no conflicts of interest to disclose.

HUMAN PARTICIPANT PROTECTION

This study collected only publicly available data and did not involve human participants. No institutional review board approval was needed.

REFERENCES

1. Halpern SD, Truog RD, Miller FG. Cognitive bias and public health policy during the COVID-19 pandemic. *JAMA*. 2020;324(4):337–338. https://doi.org/10.1001/jama.2020.11623

2. World Health Organization. Coronavirus disease (COVID-19) situation report – 71. 2020. Available at: https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200331-sitrep-71-covid-19.pdf?sfvrsn=4360e92b_6. Accessed June 22, 2020.

3. Sen S, Karaca-Mandic P, Georgiou A. Association of stay-at-home orders with COVID-19 hospitalizations in 4 states. *JAMA*. 2020;323(24):2522–2524. https://doi.org/10.1001/jama.2020.9176

4. Bedford J, Enria D, Giesecke J, et al. COVID-19: towards controlling of a pandemic. *Lancet*. 2020; 395(10229):1015–1018. https://doi.org/10.1016/S0140-6736(20)30673-5

5. Koo JR, Cook AR, Park M, et al. Interventions to mitigate early spread of SARS-CoV-2 in Singapore: a modelling study. *Lancet Infect Dis*. 2020;20(6):678–688. https://doi.org/10.1016/S1473-3099(20)30162-6

6. Nussbaumer-Streit B, Mayr V, Dobrescu AI, et al. Quarantine alone or in combination with other public health measures to control COVID-19: a rapid review. *Cochrane Database Syst Rev*. 2020;4(4): CD013574. https://doi.org/10.1002/14651858.CD013574

7. Burke J. South African police fire rubber bullets at shoppers amid lockdown. *The Guardian*. March 28, 2020. Available at: https://www.theguardian.com/world/2020/mar/28/south-africa-police-rubber-bullets-shoppers-covid-19-lockdown. Accessed June 5, 2020.

8. Philippines: President Duterte gives "shoot to kill" order amid pandemic response. Amnesty International. April 2, 2020. Available at: https://www.amnesty.org/en/latest/news/2020/04/philippines-president-duterte-shoot-to-kill-order-pandemic. Accessed June 2, 2020.

9. Coronavirus: police get new powers to enforce protection. *BBC News*. March 26, 2020. Available at: https://www.bbc.com/news/uk-52053527. Accessed June 2, 2020.

10. Contact ban or curfew: what rules apply now? And how long [in German]? *FOCUS Online*. Available at: https://www.focus.de/finanzen/recht/ausgangssperre-oder-kontaktverbot-welche-regeln-fuer-ihr-bundesland-gelten_id_11793149.html. Accessed July 29, 2020.

11. Coronavirus: contact ban should apply until after Easter [in German]. *Berliner Morgenpost*. Available at: https://www.morgenpost.de/politik/article228706533/Coronavirus-Corona-Merkel-Ausgangssperre-Kontaktverbot-soll-bis-nach-Ostern-gelten.html. Accessed July 29, 2020.

12. Robert Koch Institute. COVID-19 Germany [in German]. Available at: https://experience.arcgis.com/experience/478220a4c454480e823b17327b2bf1d4/page/page_1. Accessed June 4, 2020.

13. Epidemiologisches Bulletin 2020 27/28 [in German]. Berlin, Germany: Robert Koch Institute; 2020.

14. Wallinga J, Lipsitch M. How generation intervals shape the relationship between growth rates and reproductive numbers. *Proc Biol Sci*. 2007;274(1609):599–604. https://doi.org/10.1098/rspb.2006.3754

15. Wallinga J, Teunis P. Different epidemic curves for severe acute respiratory syndrome reveal similar impacts of control measures. *Am J Epidemiol*. 2004;160(6):509–516. https://doi.org/10.1093/aje/kwh255

16. Obadia T, Haneef R, Boëlle PY. The R0 package: a toolbox to estimate reproduction numbers for epidemic outbreaks. *BMC Med Inform Decis Mak*. 2012;12(1):147. https://doi.org/10.1186/1472-6947-12-147

17. Katz J, Sanger-Katz M. Coronavirus deaths by US state and country over time: daily tracking. *New York Times*. March 21, 2020. Available at: https://www.nytimes.com/interactive/2020/03/21/upshot/coronavirus-deaths-by-country.html. Accessed June 4, 2020.

18. Li Q, Guan X, Wu P, et al. Early transmission dynamics in Wuhan, China, of novel coronavirus–infected pneumonia. *N Engl J Med*. 2020;382(13):1199–1207. https://doi.org/10.1056/NEJMoa2001316

19. Babiarz KS, Miller G, Yi H, Zhang L, Rozelle S. New evidence on the impact of China's New Rural Cooperative Medical Scheme and its implications for rural primary healthcare: multivariate difference-in-difference analysis. *BMJ*. 2010;341(7779):c5617. https://doi.org/10.1136/bmj.c5617

20. Gotanda H, Jha AK, Kominski GF, Tsugawa Y. Out-of-pocket spending and financial burden among low income adults after Medicaid expansions in the United States: quasi-experimental difference-in-difference study. *BMJ*. 2020;368:m40. https://doi.org/10.1136/bmj.m40

21. Ryckman T, Robinson M, Pedersen C, Bhattacharya J, Bendavid E. Impact of Feed the Future initiative on nutrition in children aged less than 5 years in sub-Saharan Africa: difference-in-differences analysis. *BMJ*. 2019;367:l6540. https://doi.org/10.1136/bmj.l6540

22. Chang K. A different way to chart the spread of coronavirus. *New York Times*. March 20, 2020. Available at: https://www.nytimes.com/2020/03/20/health/coronavirus-data-logarithm-chart.html. Accessed June 4, 2020.

23. Nishiura H, Linton NM, Akhmetzhanov AR. Serial interval of novel coronavirus (COVID-19) infections. *Int J Infect Dis*. 2020;93:284–286. https://doi.org/10.1016/j.ijid.2020.02.060

24. Destatis Statistisches Bundesamt Deutschland. GENESIS-Online [in German]. 2020. Available at: https://www-genesis.destatis.de/genesis/online. Accessed June 1, 2020.

25. Bundesagentur für Arbeit. Statistics by region [in German]. Available at: https://statistik.arbeitsagentur.de/DE/Navigation/Statistiken/Statistiken-nach-Regionen/Statistiken-nach-Regionen-Nav.html. Accessed June 2, 2020.

26. Yang Y, Atkinson PM, Ettema D. Analysis of CDC social control measures using an agent-based simulation of an influenza epidemic in a city. *BMC Infect Dis*. 2011; 11(1):199. https://doi.org/10.1186/1471-2334-11-199

27. Beckett L.Older people would rather die than let COVID-19 harm US economy—Texas official. *The Guardian*. March 24, 2020. Available at: https://www.theguardian.com/world/2020/mar/24/older-people-would-rather-die-than-let-covid-19-lockdown-harm-us-economy-texas-official-dan-patrick. Accessed June 4, 2020.

28. Trump D. President Trump (@POTUS) Twitter. com. Available at: https://www.twitter.com/potus?lang+en. Accessed June 2, 2020.