Joint Discussion Paper
Series in Economics

by the Universities of

Aachen · Gießen · Göttingen
Kassel · Marburg · Siegen

ISSN 1867-3678

No. 11-2024

Jenny Bethäuser

Impact of Policy Measures and Behavior on the COVID Pandemic in Germany

Impact of Policy Measures and Behavior on the COVID Pandemic in Germany

Jenny Bethäuser*
jenny.bethaeuser@wi.jlug.de

June 10, 2024 †

Abstract

Critics protest loudly against restrictions imposed by politicians during the COVID-19 pandemic in Germany: Mandatory masks, lockdowns, school and business closures. This paper examines (1) the extent to which these policies have indirectly contributed to limiting the number of COVID-19 cases and deaths by forcing people to practice social distancing, and (2) the extent to which people have adjusted their social distancing behavior on their own based on information about national case and fatality numbers and therefore directly limit the number of COVID-19 cases and deaths. The panel analysis on federal state level in Germany finds that substantial declines in COVID-19 case and death growth rates are attributable to private behavioral response, but policies played an important role as well. A change in policies explains a large fraction of changes in social distancing behavior, why both policies and national information are important determinants of federal COVID-19 cases and deaths. Due to the lack of cross-sectional variation, there is uncertainty about the effect of mask mandate.

Keywords: *COVID-19; Coronavirus; Cases; Deaths; Pandemic; Politics; Mask Mandate; Behavior; Causal Inference; Panel Data.*

JEL Classification: *C33; C55; I12; I18.*

Data Accessibility: *The data set generated and analyzed during this study is available from the author upon request.*

*Department of Economics, Justus Liebig University Giessen, Germany.
†Thanks to Prof. Peter Winker and Prof. Mirjam Stockburger for fruitful comments.

I Introduction

The COVID-19 pandemic, caused by the SARS-CoV-2 virus, emerged as a global health crisis in early 2020, rapidly transforming into an unprecedented challenge for public health systems worldwide. In response, governments and health authorities implemented a range of non-pharmaceutical interventions (NPIs) to control the spread of the virus, including social distancing, lockdowns, mask mandates, and restrictions on public gatherings. Germany, like many other countries, adopted a multifaceted approach to pandemic management, tailoring policy measures to evolving epidemiological landscapes and public health needs. However, these interventions sparked significant public debate, with critics vocally opposing the restrictions imposed by politicians.

The literature on NPIs in mitigating the spread of COVID-19 offers a rich tapestry of findings, revealing the multifaceted impacts of these interventions across different settings and methodologies. A core theme emerging from the literature is the clear effectiveness of specific NPIs, such as mask mandates, social distancing measures, and lockdowns, in reducing COVID-19 transmission and mortality. Chernozhukov et al. (2021) and Bo et al. (2021) provide robust evidence from the United States (US) and a global dataset of 190 countries, respectively, highlighting the crucial role of these policies in curbing the spread of the virus. These findings are echoed in the work of Islam et al. (2020), which underscores the effectiveness of early lockdowns through a discontinuous time series analysis across 149 countries. Complementary analyses by Esra et al. (2020) further support the impact of household restrictions and compulsory mask-wearing in a multi-country context, including the US.

The diversity of methodological approaches in evaluating NPIs underscores the complexity of assessing their impacts. For example, Pleninger et al. (2022) utilize a vector autoregressive (VAR) model to study the effects of stringent measures in Switzerland, while Karaivanov et al. (2020) apply a panel susceptible-infected-removed (SIR) model to link rising caseloads with the easing of restrictions in Ontario, Canada. These methodological variations reveal the importance of context-specific analysis, as evidenced by studies like those of Ebrahim et al. (2020) and Wang et al. (2022), which examine workplace closures and early policy interventions across US counties and 121 countries, respectively.

The literature also points to the significant influence of socioeconomic factors and public compliance on the effectiveness of NPIs. Jalali et al. (2020) highlight the role of health disparities and noncompliance with stay-at-home recommendations in the US, suggesting that the success of NPIs is partially dependent on societal behaviors and inequalities. Similarly, studies by Chan et al. (2021) and Duhon et al. (2021) explore how socioeconomic determinants affect NPI outcomes, with Chan et al. (2021) noting the variability in NPIs effectiveness based on such factors as well.

Insights into the comparative efficacy of different NPIs and their policy implications are provided by studies like those of Siedner et al. (2020) and Liu et al. (2021), which examine the impact of social distancing and school closures across the United States. The research collectively suggests that while certain NPIs are universally effective, the optimal mix of interventions may vary based on local conditions and capacities. Furthermore, studies such as those by Amuedo-Dorantes et al. (2021) and Kovacs et al. (2020) use the Difference-in-Differences model to analyze the timing of lockdowns and the impact of mandatory masks, offering valuable insights for policymakers on the timing and implementation of NPIs to maximize their effectiveness.

In conclusion, the reviewed literature underscores the critical role of NPIs in controlling the COVID-19 pandemic, with a consensus on the general effectiveness of measures such as mask-wearing, social distancing, and lockdowns. However, the impact of these interventions is modulated by factors including the timing of implementation, public compliance, and socioeconomic variables.

Despite the significant body of research on the effectiveness of NPIs in controlling COVID-19 spread, there remains a pressing need to examine the specific impact of policy measures and behavioral responses within the German context. While studies have explored the aggregate effects of NPIs on infection rates and mortality globally, the nuanced impact of such interventions, coupled with public adherence to guidelines in Germany, warrants closer examination. The variation in infection rates and outcomes across different regions within the country suggests that local factors, including policy implementation and community behaviors, may significantly influence the pandemic's dynamics.

This study aims to fill the gap in the literature by providing a comprehensive analysis of the causal impact of policy measures and public behavior on the COVID-19 pandemic in Germany by examining two critical dimensions: (1) the extent to which policy measures have indirectly influenced COVID-19 case and death rates through enforced social distancing, and (2) the degree to which individuals voluntarily modified their social distancing behaviors in response to information regarding national case and fatality trends, thereby directly impacting the pandemic's trajectory. By offering a comprehensive examination of the interplay between policy measures and public behavior in Germany's fight against COVID-19, this research aims to contribute valuable insights into the effectiveness of NPIs and the critical role of informed public compliance.

After setting the stage with a theoretical framework by Chernozhukov et al. (2021) in chapter II, chapter III describes the data and methods for investigating the pandemic's dynamics. The empirical results in chapter IV highlight how policies and individual behaviors impact COVID-19 cases and deaths, which is then discussed in relation to existing literature in chapter V. The paper concludes in chapter VI by summarizing findings, acknowledging limitations, and suggesting avenues for further research.

II Framework

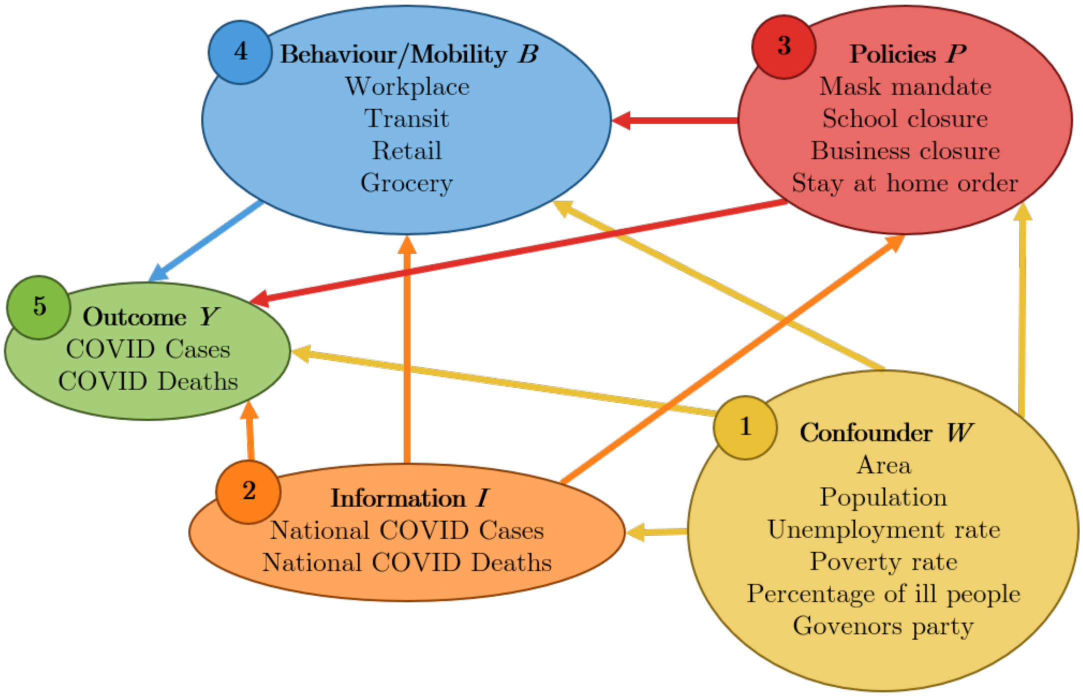


Figure 1: Interaction diagram.

The objective of this study is to elucidate the impact of policy measures and changes in population behavior on COVID-19 case and death rates. I will use the causal model by Chernozhukov et al. (2021), introduced through the Wright-style causal diagram shown in Figure 1 that illustrates the conceptual framework for the estimation results presented later in Chapter IV. The policy measures (P) considered in this study include mandatory face masks, school and business closures, and domestic lockdown. These measures are expected to have both direct and indirect effects on the spread of the virus, as they not only reduce transmission of the virus but also influence social distancing behavior. Specifically, school and business closures as well as domestic lockdowns are expected to have a strong indirect effect on reducing the growth of cases and deaths by restricting gatherings and enforcing social distancing. In contrast, mandatory use of face masks is expected to have a direct effect on reducing the transmission of aerosols, thereby slowing down the spread of the virus.

Social distancing behavior (B) is determined by changes in the population's time spent at work, in public transit, retail shops, or supermarkets. By spending more time at home, the transmission of COVID-19 is limited, contributing to lower growth rates of cases and deaths.

Moreover, information (I) on national case and death figures has an impact on political measures and the mobility of the population. In the past, some individuals voluntarily isolated themselves to avoid being infected with the virus, irrespective of the political regulations in place. This also contributes to lower case and death rates.

It is acknowledged that the effects of policy measures will vary across different federal states in Germany. In order to control for state-specific differences, various confounding factors (W) such as area, population, unemployment and poverty rates, proportion of people subject to illness, and the governing party are used as covariates.

As demonstrated in the numbered graph, policy measures (3) to contain the virus are initially adopted in each federal state based on confounding factors (1) and information on national case and death figures (2). The changes in the population's behavior (4) subsequently become apparent, and the overall impact on the number of cases and deaths (5) is observed.

III Methods and Data

To express the contents of Figure 1 mathematically, the following equations 1 – 5 from Chernozhukov et al. (2021) are employed and subsequently estimated in Chapter IV.

$$(\text{BPI} \to \text{Y})\text{: } Y_{it+l} = \alpha B_{it} + \pi P_{it} + \mu I_{it} + \delta_Y W_{it} + \varepsilon_{it}^Y \tag{1}$$

$$(\text{PI} \to \text{B})\text{: } B_{it} = \beta P_{it} + \gamma I_{it} + \delta_B W_{it} + \varepsilon_{it}^B \tag{2}$$

Inserting Equation 2 into Equation 1 yields:

$$(\text{PI} \to \text{Y})\text{: } Y_{it+l} = (\alpha\beta + \pi)P_{it} + (\alpha\gamma + \mu)I_{it} + \bar{\delta}W_{it} + \bar{\varepsilon_{it}} \tag{3}$$

Therefore, the projection equation $Y \sim PI$:

$$(\text{Y} \sim \text{PI})\text{: } Y_{it+l} = aP_{it} + bI_{it} + \bar{\delta}W_{it} + \bar{\varepsilon_{it}} \tag{4}$$

should obey a and b as:

$$a = (\alpha\beta + \pi) \text{ and } b = (\alpha\gamma + \mu) \tag{5}$$

In the equations, B_{it} denotes variables for social distancing behavior in state i at time t, while P_{it} represents policies implemented in state i at time t. The outcome variable Y_{it+l} reflects either case growth with a 14-day lag or death growth with a 21-day lag. Additionally, I_{it} encompasses a set of information variables, and W_{it} collects all confounding variables. The primary focus is to explain the outcome variable Y after defining policies P and behavior B. For more detailed information on testable implications and identification, refer to Chernozhukov et al. (2021).

The panel dataset was constructed to estimate Equations 1 to 3. The dataset comprises daily observations from February 15, 2020, to December 31, 2021, across all 16 federal states in Germany, resulting in a total of 10,976 observations (n: 16 federal states; t: 686 days).

The information on COVID cases (C) and deaths (D) was sourced from the daily situation reports of the Robert Koch Institute for both individual federal states and Germany as a whole (Robert Koch Institut 2022). Missing values on weekends or holidays were supplemented by interpolation or values from weekly reports (Robert Koch Institut 2020). To measure the outcome variable for empirical analysis, Equations 6 and 7 transforme the absolute number of cases and deaths into a weekly growth rate, where ΔC_t and ΔD_t represent the number of new cases within the last 7 days. Daily new cases and deaths are affected by the timing of reporting and testing. Focusing on weekly cases smooths out idiosyncratic daily fluctuations as well as periodic fluctuations associated with days of the week.

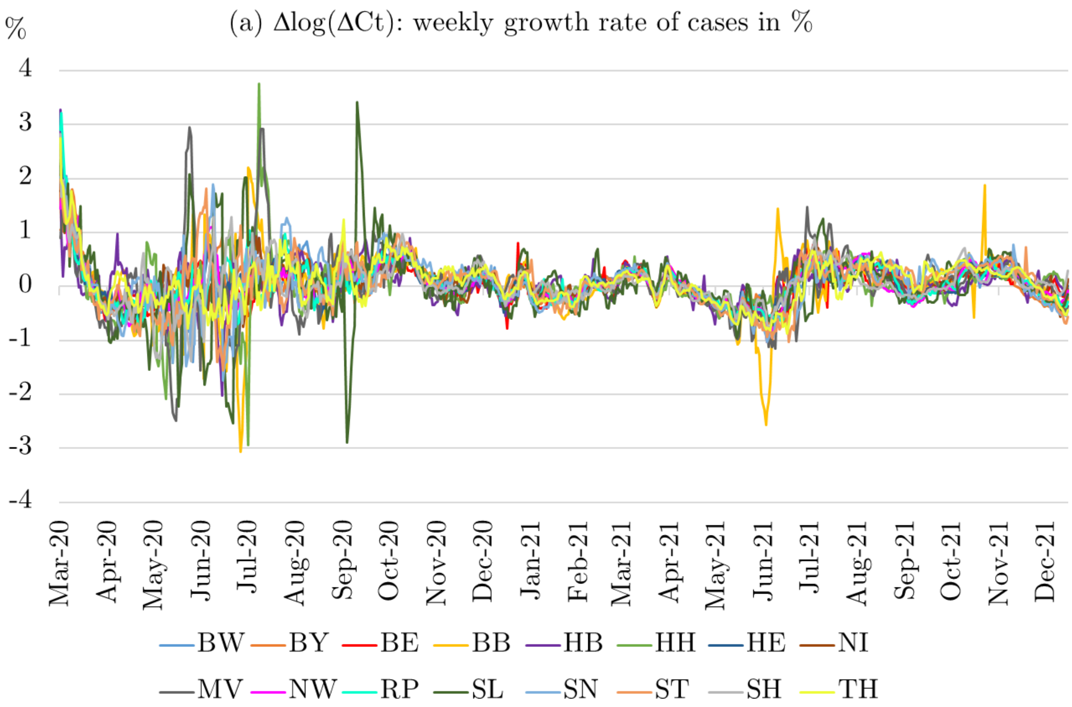
$$\Delta log(\Delta C_t) = log(\Delta C_t) - log(\Delta C_{t-7}) \tag{6}$$

$$\Delta log(\Delta D_t) = log(\Delta D_t) - log(\Delta D_{t-7}) \tag{7}$$

Figure 2 displays the (a) case and (b) death growth over the entire period for all 16 federal states, illustrating different phases of volatility. From March to October 2020, the weekly growth rate of cases fluctuated between +3% and -3%, while the growth rate of deaths fluctuated between +2.5% and -2.5%. This was followed by a period of less volatile patterns until March 2021 when the volatility in the growth rate of deaths increased considerably again. These figures demonstrate noticeable differences between federal states and over time that require further analysis.

To measure social distancing behavior B, Google COVID Community Mobility Reports (Google 2020, 2021) based on Google Maps location data were utilized. The data in the categories of workplaces (*workplace*), retail and leisure (*retail*), grocery stores and pharmacy (*grocery*), and transit stations (*transit*) indicate the percentage change in visit intensity relative to the reference period between January 3, 2020, and February 6, 2020, when there was no evidence of COVID in Germany yet (Google 2022). A moving average was constructed over one week to mitigate day-specific outliers. On Sundays, in particular, all the categories mentioned above are significantly less frequented than on weekdays.

Figure 3 depicts the changes in (a) overall visit intensity and specifically for (b) workplaces, (c) retail, (d) grocery, and (e) transit in each federal state of Germany for every date. The graphs exhibit a significant decrease in visit intensity in April 2020, when the country experienced its first surge in COVID-19 cases. Another sharp decline occurred around Christmas and New Year for both 2020 and 2021. However, the patterns between these two periods are not highly comparable. In most federal states, the frequency of visiting workplaces and transit remained permanently below the baseline level, while supermarkets were visited more frequently in 2021 than during the



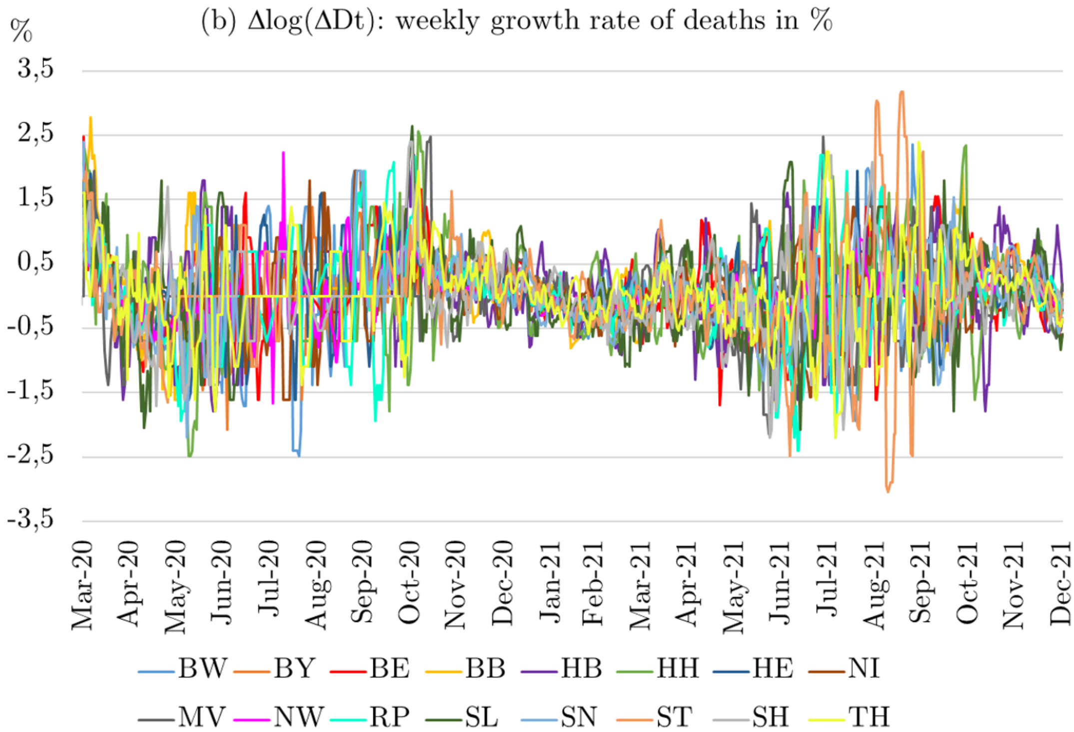


Figure 2: Evolution of case and death growth across federal states.

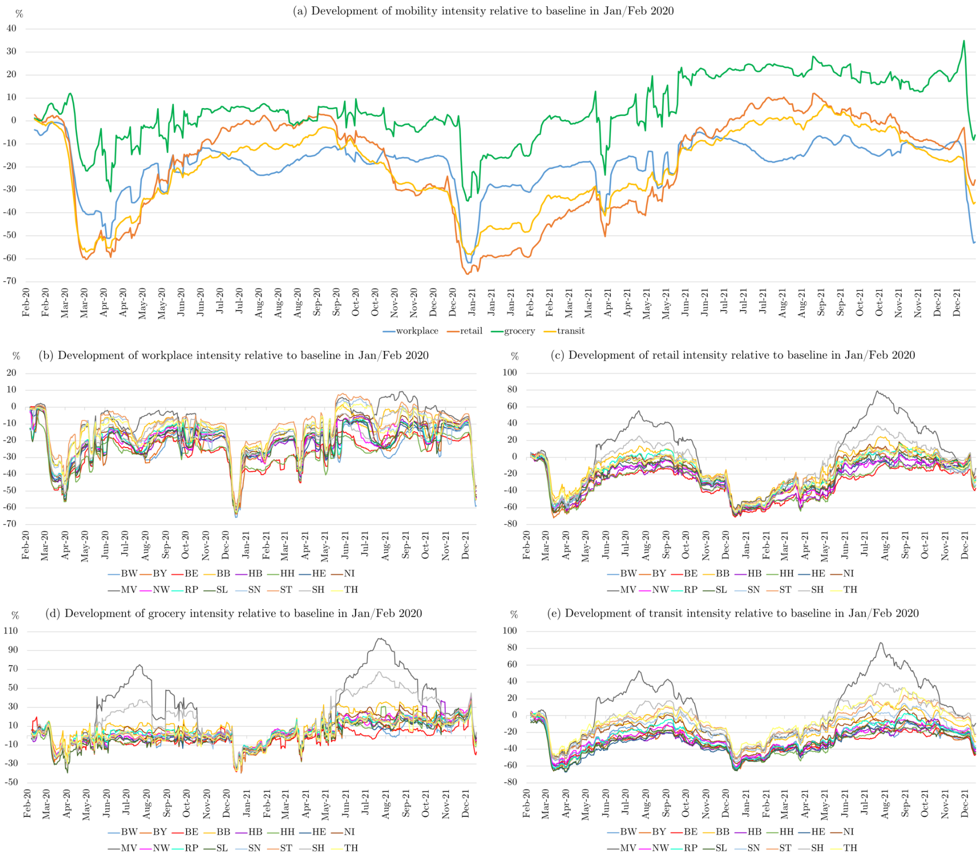


Figure 3: Evolution of google mobility reports across federal states.

reference period of January 2020.

Germany implemented several political measures (P) to contain the spread of COVID-19. These measures include a stay-at-home order ($stayathome$), mandatory face masks in stores, public transportation, and public buildings ($maskmandate$), mainly secondary school closures ($closedschool$), closures of non-essential stores above or below $800m^2$, closure of indoor dining areas in restaurants, but not for pick-up and delivery service, and movie theater closures. The corona ordinances, official press releases, and homepages of federal states and other governmental institutions were utilized to determine the policies imposed in each federal state [1]. All measures were converted into dummy variables, with a value of 1 indicating that the measure was in effect, and a value of 0 indicating that it was not. To address issues with multicollinearity, an index was created by taking

1. (dpa-infocom GmbH 2020; focus.de 2020; Bavarian State Ministry for Health and Care 2022; Government of the State Baden-Württemberg 2022; Hesse 2020; Hessian Cabinet 2021; Landesportal Schleswig-Holstein 2020a, 2020b, 2021; Lower Saxony Ministry of Social Affairs, Health and Equality 2020; Minister for Education, Science and Culture and Prime Minister and Minister for Social Affairs, Health, Youth Family and Seniors 2021; Minister for Social Affairs, Health, Youth Family and Seniors 2020; Ministry of Labor, Social Affairs, Health, Women and Family Affairs 2022; Ministry of Lower Saxony for Social Affairs, Health and Equality 2021; Ministry of Social Affairs, Health, Integration and Consumer Protection of the State of Brandenburg 2022; Niedersächsisches Kultusministerium 2020; Saxon State Ministry for Social Affairs and Social Cohesion 2022; State Government of Rhineland-Palatinate 2020; Authority for Health and Consumer Protection 2020a, 2020b; Authority for Labor, Health, Social Affairs, Family and Integration 2020; Government of the Saarland 2022; Minister of Labor, Heath and Social Affairs of the State of North Rhine-Westphalia 2022; Minister of Social Affairs, Health and Sport 2022; Minister of Social Affairs, Labor, Health and Demography 2021; Senate of Berlin 2022; Senate of Hamburg 2022; Senator for Health, Women and Consumer Protection 2022; ZDFheute 2020; State Gorvernment of Saxony-Anhalt 2022)

the average of closed non-essential stores above or below $800m^2$, restaurants, and movie theaters, resulting in a value between 0 and 1 (*businessclosureindex*).

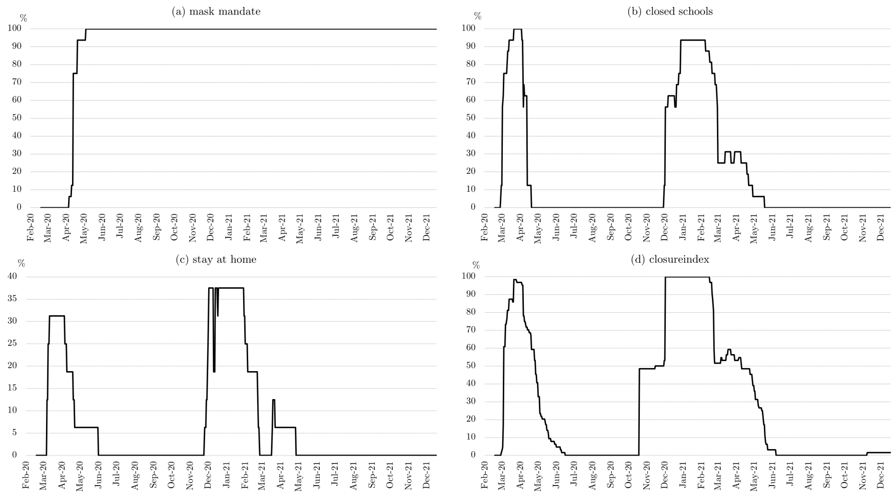


Figure 4: Share of federal states with each policy in place.

Figure 4 illustrates the percentage of states that implemented each of the remaining four policies at each date. There was considerable variation across states in terms of the duration during which the policies were active, with the exception of (a) mandatory face masks in stores, public transportation, and public buildings. All federal states implemented mandatory face masks within one month between 20.04. and 18.05.2020 and retained this policy until the end of 2021. This makes it challenging to differentiate the impact of mandatory face masks from aggregate time series variation. The other three figures (b), (c) an (d) exhibit a seasonal effect, as there were no restrictive policy measures in any of the federal states during the summer months.

The confounding variables (W) included in the analysis were *area*, *population*, *unemploymentrate*, *povertyrate*, the proportion of people subject to illness (*percentage ofillpeople*), and the governing party (*govenorsparty*). These were motivated by Wheaton and Kinsella Thompson (2020), who found that case growth is associated with factors such as residential density and per capita income. The data on area, population, and unemployment rates of the federal states were obtained from the Federal Statistical Office of Germany (Federal Statistical Office of Germany (Destatis) 2022, 2020). Poverty rates were reported in the Poverty Report for Germany (Pieper et al. 2020). Population, area, and poverty rate were fixed over time as they were reported for 2019 only, while the unemployment rate was reported monthly. Information on the governing party was obtained from the respective official homepages and changed for some states (BE, BW, HH, MV, RP, and ST) due to federal state elections during the observational period[2].

2. (Bavarian State Government 2022; Berlin State Centre for Political Education 2022; Brandenburg State Portal 2022; Hesse State Government 2022; Saxony-Anhalt State Portal 2022; Schleswig-Holstein State Portal 2022; Senate Office of Hamburg 2022; State Chancellery of Lower Saxony 2022; State Chancellery of Saarland 2022; State Chancellery of Saxony 2022; State Chancellery Unesco World Heritage City Hall of Bremen 2022; State Government of Thuringia 2022; State Ministry of Baden-Württemberg 2022; Country Portal of Mecklenburg-Western Pomerania

Descriptive statistics for all variables can be found in Table 1.With this data, the equations are now estimated individually. All models are estimated as random effect models, with standard errors clustered at the federal state level, to account for heterogeneity and serial correlation within each state.

Table 1: Summary statistics of underlying data set.

	Outcome Y:		*Policies P:*			
	COVID Cases C	COVID Deaths D	mask mandate	stayat home	closed schools	business closureindex
Min	0.000	0.000	0.0000	0.0000	0.0000	0.0000
Mean	139 228	3 224	0.9148	0.0667	0.1881	0.2919
Max	1 378 107	20 308	1.0000	1.0000	1.0000	1.0000

	Information I:		*Behavior B:*			
	National Cases C_{nat}	National Deaths D_{nat}	workplaces	retail	grocery	transit
Min	196	12	-65.714	-72.143	-39.571	-67.000
Mean	2 227 636.3	51 586.76	-18.901	-19.118	4.944	-20.528
Max	7 130 720.0	111 765.0	9.429	79.286	103.143	87.000

	Confounder W:					
	population	area	unemployment rate	poverty rate	percentageof illpeople	govenors party
Min	681 202	419.4	2.90%	11.90%	0.00%	1.00
Mean	5 197 919	22 348.8	6.59%	16.91%	2.24%	2.13
Max	17 947 221	70 541.6	12.00%	24.90%	15.98%	4.00

IV Results

The first estimation aims to investigate how policies and information affect social distancing behaviour ($PI \rightarrow B$). As outlined in Equation 2, there are a total of 16 estimations to be conducted, given the four behavioural variables (*workplaces*, *retail*, *grocery*, and *transit*) and four ways of including information. Specifically, cases C and deaths D can be used with federal data only or in combination with nation-wide values. Table 2 presents the results for the case information, while Table 3 presents the results for the death information.

Table 2 illustrates the impact of political measures on behavior variables across the first four rows, and the effect of information dissemination through case numbers in rows four to eight. The differentiation between columns 1-4 and 5-8 lies in the employment of regional case numbers as information in the first block, and the inclusion of national case numbers in the second block. The primary focus of our analysis is the effect of political measures on behavior. Across all specifications, the anticipated negative impacts of school closures and business shutdowns are evident,

2022; State Government of North Rhine-Westphalia 2022; State Government of Rhineland-Palatinate 2022) indicating a reduction in public mobility. Conversely, the implementation of mask mandates exhibits positive behavioral effects. This can be partially attributed to an increased sense of safety amongst individuals wearing masks, leading to greater public presence, and also to the initial phase where activities were permitted provided masks were worn. The outcomes of stay-at-home orders present a mixed picture. There is a negative impact on workplace attendance and positive effects on retail, although the impacts on grocery and transit appear to be insignificant. Given that grocery shopping was largely permitted, no significant change in visit intensity is noted. To exemplify the magnitude of these effects, consider the most evident scenario: the enactment of a business closure mandate led to a 34 percentage point decline in retail store visitation intensity compared to the pre-COVID-19 period. Regarding the information variables, the absolute case count exhibits a negative effect on behavior at both regional and national levels. Unexpectedly, the case growth rate over the past week shows a positive effect on behavior. In conclusion, variation in political measures and information variables account for between 47% and 82% of the variance in visit intensity, thus explaining a substantial portion of the behavioral changes. Comparing columns (1)-(4) with columns (5)-(8), the explanatory power of the model is marginally higher when national case numbers are included as information.

Table 2: Effect of policies and information on behavior ($PI \rightarrow B$) with cases as information.

	Dependent variable:							
	workplaces	retail	grocery	transit	workplaces	retail	grocery	transit
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
maskmandate	11.608***	17.003***	13.185***	21.997***	12.249***	18.528***	14.448***	23.251***
	(0.424)	(0.559)	(0.561)	(0.536)	(0.426)	(0.556)	(0.564)	(0.537)
closedschool	−1.408***	−2.724***	−1.465***	−0.572	−1.763***	−3.503***	−1.767***	−1.121***
	(0.327)	(0.399)	(0.398)	(0.380)	(0.327)	(0.393)	(0.396)	(0.377)
stayathome	−3.257***	1.621***	0.817*	0.641	−3.135***	1.725***	0.713	0.675
	(0.372)	(0.452)	(0.450)	(0.429)	(0.370)	(0.443)	(0.446)	(0.425)
businessclosureindex	−10.340***	−34.774***	−9.031***	−21.677***	−9.546***	−32.735***	−7.626***	−20.073***
	(0.381)	(0.473)	(0.472)	(0.451)	(0.388)	(0.476)	(0.480)	(0.457)
dlogdC	2.022***	6.790***	3.638***	4.745***	0.049	2.454***	1.387***	1.535***
	(0.194)	(0.235)	(0.234)	(0.224)	(0.261)	(0.313)	(0.315)	(0.300)
logdC	−0.699***	−3.562***	−2.609***	−2.786***	−0.781***	−1.939***	−0.519**	−1.227***
	(0.075)	(0.093)	(0.093)	(0.089)	(0.159)	(0.200)	(0.202)	(0.192)
dlogdCnat					4.316***	8.781***	3.971***	6.334***
					(0.368)	(0.440)	(0.444)	(0.422)
logdCnat					−0.005	−2.289***	−2.791***	−2.152***
					(0.183)	(0.233)	(0.235)	(0.224)
Constant	−32.266***	−6.153	−2.601	−30.482**	−32.671***	3.347	9.347	−21.442
	(1.438)	(6.825)	(12.042)	(14.479)	(1.658)	(6.902)	(12.090)	(14.512)
State variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	10,480	10,480	10,480	10,480	10,480	10,480	10,480	10,480
R^2	0.471	0.813	0.592	0.724	0.478	0.820	0.599	0.730
Adjusted R^2	0.470	0.813	0.591	0.723	0.477	0.820	0.598	0.730
F Statistic	9,309.803***	45,447.340***	15,167.000***	27,417.270***	9,583.011***	47,714.530***	15,604.790***	28,362.910***

Note: State variables include population, area, unemploymentrate, povertyrate, percentageofillpeople and govenorsparty *p<0.1; **p<0.05; ***p<0.01

In Table 3, the focus shifts from case numbers to mortality numbers, both regional and national, as the variables of information. The outcomes do not significantly deviate from those observed in Table 2: there are negative effects from school closures and business shutdowns, and positive effects from mask mandates. For stay-at-home orders, previously insignificant effects on groceries and transit are now significant and positive. As mentioned, shopping was still permitted during lockdowns. The direction of the effects of the information variables, namely the death counts and their growth rate, is comparable to that of the case numbers and their growth rate in Table 2; however, the magnitude of the effects is noticeably smaller. This suggests that the population was more influenced by reports on case numbers than by those on death counts in terms of altering their behavior. The explanatory power across all columns remains comparable to Table 2.

From the previous estimates, one can understood the interplay between political measures, information dissemination, and social distancing behavior. Table 4 presents the estimation results from the next step, examining the relationship among these three factors – policy, behavior, and information – and the outcome variables, namely case and death growth ($BPI \rightarrow Y$). Given the temporal lag between infection and the confirmation of a COVID-19 case or death, the outcome variables are lagged by 14 days for case numbers and 21 days for death counts (Chernozhukov et al. 2021). The rows in the table display first the four political measures, followed by the four behavioral variables, and then the four potential information variables. Columns 1 and 2 focus on case growth as the outcome, while columns 3 and 4 concentrate on death growth. Columns 2 and 4 additionally incorporate national case and death numbers, respectively, alongside regional figures. Overall, the table reveals that all these variables together account for merely 17% and 20% of the variance in case growth and a notably lower 4% and 3% of the variance in death growth, respectively.

Table 3: Effect of policies and information on behavior ($PI \rightarrow B$) with deaths as information.

	Dependent variable:							
	workplaces	retail	grocery	transit	workplaces	retail	grocery	transit
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
maskmandate	12.768***	16.488***	10.451***	20.770***	13.134***	17.971***	10.608***	22.150***
	(0.477)	(0.534)	(0.595)	(0.530)	(0.480)	(0.467)	(0.586)	(0.474)
closedschool	−1.171***	−0.618*	−0.415	0.727**	−1.258***	−1.989***	−0.946**	−0.522
	(0.332)	(0.367)	(0.409)	(0.364)	(0.332)	(0.320)	(0.401)	(0.324)
stayathome	−3.070***	3.358***	1.394***	1.889***	−3.129***	2.156***	0.873*	0.775**
	(0.381)	(0.420)	(0.469)	(0.417)	(0.381)	(0.366)	(0.459)	(0.371)
businessclosureindex	−12.046***	−25.379***	−9.510***	−13.889***	−11.733***	−12.439***	−3.435***	−1.867***
	(0.464)	(0.513)	(0.572)	(0.509)	(0.514)	(0.501)	(0.628)	(0.508)
dlogdD	0.299**	2.859***	0.183	2.009***	−0.183	−0.485***	−0.679***	−1.047***
	(0.141)	(0.156)	(0.174)	(0.155)	(0.164)	(0.158)	(0.198)	(0.160)
logdD	−0.095	−6.403***	−2.219***	−4.980***	0.242	0.394***	0.656***	1.305***
	(0.098)	(0.108)	(0.120)	(0.107)	(0.155)	(0.151)	(0.190)	(0.153)
dlogdDnat					1.812***	2.439***	−1.948***	2.036***
					(0.301)	(0.290)	(0.364)	(0.294)
logdDnat					−0.430**	−9.635***	−4.163***	−8.915***
					(0.170)	(0.167)	(0.210)	(0.170)
Constant	−37.209***	−18.252*	−11.497	−39.055*	−36.062***	13.916	2.861	−9.309
	(3.065)	(9.973)	(14.358)	(20.794)	(3.121)	(10.014)	(14.387)	(20.812)
State variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	10,256	10,256	10,256	10,256	10,256	10,256	10,256	10,256
R^2	0.461	0.845	0.578	0.747	0.463	0.883	0.596	0.801
Adjusted R^2	0.461	0.845	0.577	0.747	0.462	0.883	0.596	0.801
F Statistic	8,766.409***	55,794.220***	14,001.470***	30,279.480***	8,835.235***	77,228.970***	15,122.350***	41,191.580***

Note: State variables include population, area, unemploymentrate, povertyrate, percentageofillpeople and govenorsparty   *p<0.1; **p<0.05; ***p<0.01

Among the individual variables, positive effects of mask mandates, school closures, and business shutdowns on the growth of case numbers are identified. This suggests that while the population may not have congregated in schools or businesses, gatherings occurred elsewhere, leading to infections. Stay-at-home orders have been found to decrease the growth of death numbers; specifically, the measures have led to a reduction in the case growth rate by 7.6%. Regarding behavioral variables, an increase in visit intensity in retail and transit logically corresponds with more people congregating in close quarters, leading to higher infection rates and thus case growth. Conversely, an increase in visit intensity at groceries and workplaces shows a negative effect, meaning that as visit intensity in these areas rises, the growth of cases decreases. This is likely because access to these locations was permitted only when the risk of infection was low or when overall national case numbers were low. The effects on the death rate growth are smaller and, in some instances, insignificant.

The analysis thus far has illustrated the complexity of concurrently examining political measures and behavioral changes. Consequently, Table 5 focuses solely on the effect of political measures and information on the outcome variables of case and death growth, excluding the modeling of behavior. The impact of behavioral variables is encapsulated within the policy variables.

The first two columns present the effect of policy and information variables on case growth with a reporting lag of 14 days. Both columns show positive effects of mask mandates and school closures on case growth and negative effects of stay-at-home orders and business closures on case growth, as well as negative effects regarding the increasing testing rate. When national information variables are included in Column 2, the explanatory power of the model increases to 17.4%, and the coefficients are estimated with greater precision.

Columns 3 and 4 examine death growth as the outcome variable. Apart from the positive effect of mask mandates, no significant effects of political measures can be observed. In this context, the inclusion of national information variables does not lead to a higher explanatory power.

The estimated effects of policies on behavior presented in Tables 2 and 3, as well as the effects of policies and behavior on case and death growth in Table 4, can be used to calculate the total effect of policies on the outcome variables. Given that one can observed fewer significant or insignificant effects on death rates across all specifications, the following comparison will focus only on case numbers, although the procedure for death rates would be the same.

The results of estimating $(PI \rightarrow Y)$ are largely consistent with the approach of separately estimating direct and indirect effects and then combining them. Table 6 provides an overview of the comparison of estimated coefficients, with the last column indicating the differences between the two methods of estimating the effect of policies on case and death rates. Column "Average" in Table 6 displays the average of the "Total" and "$PI \rightarrow Y$" columns. This average serves as a

Table 4: Direct effect of behavior and policies on lagged case and death growth ($BPI \rightarrow Y$).

	Dependent variable:			
	dlogdC14		dlogdD21	
	(1)	(2)	(3)	(4)
maskmandate	0.346***	0.339***	0.211***	0.056*
	(0.021)	(0.021)	(0.034)	(0.032)
closedschool	0.093***	0.070***	−0.023	−0.023
	(0.015)	(0.015)	(0.023)	(0.023)
stayathome	−0.076***	−0.070***	−0.046*	−0.042
	(0.017)	(0.017)	(0.027)	(0.026)
businessclosureindex	0.061**	0.063***	0.173***	0.148***
	(0.024)	(0.023)	(0.037)	(0.036)
workplaces	−0.005***	−0.005***	−0.0001	−0.0003
	(0.001)	(0.001)	(0.001)	(0.001)
retail	0.010***	0.007***	0.009***	0.011***
	(0.001)	(0.001)	(0.001)	(0.001)
grocery	−0.007***	−0.005***	−0.006***	−0.008***
	(0.0005)	(0.0005)	(0.001)	(0.001)
transit	0.0005	0.001**	−0.001	−0.001
	(0.001)	(0.001)	(0.001)	(0.001)
dlogdT	−0.088***	−0.151***		
	(0.024)	(0.024)		
logdC	−0.008***			
	(0.003)			
dlogdC	0.169***			
	(0.010)			
logdCnat		−0.020***		
		(0.004)		
dlogdCnat		0.398***		
		(0.017)		
logdD			−0.011*	
			(0.007)	
dlogdD			0.081***	
			(0.010)	
logdDnat				0.015*
				(0.009)
Constant	−0.215***	−0.088*	−0.058	0.015
	(0.042)	(0.050)	(0.064)	(0.068)
State variables	Yes	Yes	Yes	Yes
Observations	10,048	10,048	9,941	10,053
R^2	0.173	0.198	0.043	0.032
Adjusted R^2	0.172	0.197	0.041	0.031
F Statistic	2,098.157***	2,475.671***	440.843***	331.688***

*p<0.1; **p<0.05; ***p<0.01

Note: State variables include area, unemploymentrate and povertyrate

Table 5: Total effect of policies on case and death growth ($PI \to Y$).

	Dependent variable:			
	dlogdC14		dlogdD21	
	(1)	(2)	(3)	(4)
maskmandate	0.335***	0.325***	0.256***	0.131***
	(0.021)	(0.020)	(0.032)	(0.030)
closedschool	0.094***	0.066***	−0.022	−0.034
	(0.015)	(0.015)	(0.023)	(0.023)
stayathome	−0.040**	−0.040**	−0.019	−0.016
	(0.018)	(0.017)	(0.027)	(0.026)
businessclosureindex	−0.188***	−0.102***	0.035	0.016
	(0.017)	(0.018)	(0.031)	(0.034)
logdC	−0.027***			
	(0.003)			
dlogdC	0.229***			
	(0.010)			
logdCnat		−0.042***		
		(0.004)		
dlogdCnat		0.496***		
		(0.016)		
dlogdT	−0.134***	−0.207***		
	(0.024)	(0.024)		
logdD			−0.051***	
			(0.006)	
dlogdD			0.105***	
			(0.010)	
logdDnat				−0.043***
				(0.007)
Constant	−0.058	0.147***	−0.112**	0.136**
	(0.039)	(0.049)	(0.056)	(0.060)
State variables	Yes	Yes	Yes	Yes
Observations	10,048	10,048	9,941	10,053
R^2	0.139	0.175	0.035	0.022
Adjusted R^2	0.138	0.174	0.034	0.021
F Statistic	1,619.373***	2,124.021***	364.562***	228.641***

*p<0.1; **p<0.05; ***p<0.01

Note: State variables include area, unemploymentrate, povertyrate, percentage ofillpeople and govenorsparty simple and appealing way to combine the two estimates of the total effect, with one based on the causal structure and the other obtained from a direct estimation of the equation $PI \to Y$. The average estimate could be utilized in generating counterfactuals in subsequent analyses.

The interpretation of the results in Table 6 proceeds row by row. For mask mandates, one can observe that approximately 90% of the effect of this policy on case growth can be attributed to the direct effect, while only 10% is due to the indirect effect via behavioral change. The overall effect is significant at 0.3767, indicating that the implementation of the mask mandate results in an increase in the case growth rate by 37 percentage points. Similarly, for school closures and stay-at-home orders, the primary impact is seen in the direct effect. However, the direction of the effects between the direct and indirect components differs for both policies. A fundamentally positive direct effect of school closures on case growth is mitigated by the indirect behavioral effect. Conversely, an initially negative effect of stay-at-home orders is also mitigated by the behavioral effect, resulting in a reduced overall magnitude. Unfortunately, for all three variables, the calculated total effects and the estimated total effects significantly differ (see the Difference column). The large differences may be due to the difficulty in identifying the effect of e.g. mask mandates given a lack of cross-sectional variation. The only variable for which the effect can be estimated correctly and without significant deviation is business closures. Here, one can observe that the indirect effect via behavior constitutes the main component and is moderated in magnitude by the direct effect. Overall, the closure of businesses results in a reduction of the case growth rate by 18.27 percentage points. This is the only effect that can be reliably and plausibly estimated.

Table 6: Direct and indirect policy effects without national variables.

	Direct π (1)	Indirect $\alpha * \beta$ (2)	Total $\pi + \alpha * \beta$ (3)	$PI \to Y$ a (4)	Average $\frac{(3)+(4)}{2}$	Difference (3)-(4)
maskmandate	0.346***	0.0307***	0.3767***	0.335***	0.3559	0.0417***
	(0.021)	(0.015)	(0.014)	(0.021)		(0.003)
closedschool	0.093***	−0.0102***	0.0828***	0.094***	0.0884	−0.0112***
	(0.015)	(0.005)	(0.008)	(0.015)		(0.002)
stayathome	−0.076***	0.0271***	−0.0489***	−0.040**	−0.0445	−0.0089**
	(0.017)	(0.013)	(0.015)	(0.018)		(0.003)
businessclosureindex	0.061***	−0.2437***	−0.1827***	−0.188***	−0.1854	0.0053
	(0.024)	(0.014)	(0.012)	(0.017)		(0.003)
logdC	−0.008***	−0.0153***	−0.0233***	−0.027***	−0.0252	0.0037***
	(0.003)	(0.007)	(0.003)	(0.003)		(0.0002)
dlogdC	0.169***	0.0347***	0.2037***	0.229***	0.2164	−0.0253***
	(0.010)	(0.017)	(0.014)	(0.010)		(0.002)

*p<0.1; **p<0.05; ***p<0.01

Note: Direct effects capture the effect of policy on case growth holding behavior, information, and confounders constant. Direct effects are given by π in equation $(BPI \to Y)$ (see Tab. 4). Indirect effects capture how policy changes behavior and behavior shift case growth. They are given by α from $(BPI \to Y)$ (see Tab. 4) times β from $(PI \to B)$ (see Tab. 2 and 3). The total effect is $\pi + \beta\alpha$. Column $PI \to Y$ shows the coefficient estimates from $(PI \to Y)$ (see Tab. 5). Column Difference and Average refer to column Total and $(PI \to Y)$.
Standard errors are computed by bootstrap and clustered on state level.

V Discussion

With the onset of the COVID-19 pandemic, many governments implemented a range of political measures in an effort to slow or halt the pandemic's progression, thereby reducing both case and death numbers. This study investigated the effectiveness of these political measures in Germany, incorporating, for the first time, the indirect effects via voluntary or involuntary behavioral changes in the population. Additionally, the study explored whether individuals modify their behavior in response to information about local or national case and death numbers.

Methodologically, the study was based on Chernozhukov et al. (2021)'s causal model, adapted from his analysis of 50 US states to the 16 German federal states. Data included daily observations of cases, deaths, policy implementations, and movement patterns from Google Mobility as a proxy for behavior from the beginning of the pandemic in 2020 until the end of 2021.

The panel analysis revealed that substantial declines in COVID-19 case and death growth rates are directly attributable to policies, with private behavioral responses playing a significant role. Changes in any given policy accounted for a large fraction of changes in social distancing behavior, indicating the effectiveness of the measures. Furthermore, both regional and national information emerged as important determinants of behavior, as well as cases and deaths. Overall, the effect of business closure policies on case growth could be reliably estimated, resulting in an 18.27 percentage point reduction in case growth rate.

It was observed that all political measures influenced behavior, which is valuable information for policymakers, validating that their efforts were not in vain. However, the direction of these effects was contentious. Specifically, mask mandates showed positive effects on behavior, indicating that people exhibited less social distancing behavior when wearing masks, possibly due to a false sense of security. In contrast, school and business closures showed expected negative effects, reducing social gatherings by closing places where people could congregate. The effect of stay-at-home orders was less clear; while one would expect these measures to restrict behavior as measured by Google Mobility, the actual effects were mixed. Nevertheless, the direction of the effects of policies on behavior aligned with their effects on case growth, with stay-at-home orders reliably reducing case growth.

A major part of this study aimed to replicate Chernozhukov et al. (2021)'s analysis for the US using data for Germany. The primary difference lies in the number of federal states (16 for Germany versus 50 for the US), leading to greater variability in political measures in the US and limited covariate inclusion for Germany. Despite this, the causal model was adaptable to a different setting like Germany. However, parallel results between the two countries are limited. Chernozhukov et al. (2021)found no significant results for school closures in the US, attributed to a lack of variability across states, a situation that in Germany pertains more to the nationwide mask mandates. Since education policy is a state matter in Germany, we had sufficient variation in school closures.

Chernozhukov et al. (2021)'s US analysis suggested that keeping all businesses open would have led to 17 to 78% more cases, and not implementing stay-at-home orders would have increased cases by 6 to 63%. Our findings similarly indicate that business closures reduce case growth by 18 percentage points and stay-at-home orders by 4 percentage points. Both studies agree that individuals voluntarily reduce visits to workplaces, retail stores, grocery stores, and public transit in response to higher numbers of new cases and deaths.

Our study's differences from the US results may stem from several factors. At the time of data collection, there was no comprehensive database in Germany documenting when and where specific political measures were implemented. These data were manually compiled, introducing potential errors. While case and death numbers were quickly available after the pandemic's onset, reporting issues, especially early in the pandemic, posed challenges. Debates over whether to count deaths "with" COVID-19 or "from" COVID-19, along with temporal discrepancies in reporting, were addressed through lag structures in the model, yet the chosen 14- and 21-day lags might not fully capture all effects.

Given these limitations, it may be prudent to incorporate Germany-specific characteristics into the model and vary the political measures to include only those independently decided by federal states. Additionally, fundamental critiques of Chernozhukov et al. (2021)'s methodology, such as the use of moving averages and the loss of information on absolute case numbers, suggest that alternative metrics like the R-Factor might offer more valid outcome variables.

Practically, the study shows that Chernozhukov et al. (2021)'s model can be applied to different countries and settings, provided there are enough observational units or sufficient variability in the variables across states. However, the effects and effect sizes are not universally comparable, highlighting the need for tailored approaches in pandemic response. Regional characteristics play a significant role, as seen in the varying responsibilities for schools and the nationwide mask mandate in Germany compared to state-level decisions in the US The significant impact of social distancing behavior in both nations suggests that individuals voluntarily limit contact in response to higher transmission risks, an important feedback mechanism influencing future cases and deaths. Ignoring this voluntary response in model simulations could lead to over-predictions of future case and death numbers.

Overall, this paper provides an initial insight into the interplay of political measures, social distancing behavior, and their impact on case and death growth. However, limitations meant that only the effect of business closures could be reliably estimated, preventing a comprehensive understanding of the efficacy of NPIs. It remains crucial to determine the effectiveness of political measures and to what extent they are needed if individuals also change their behavior without enforcement.

VI Conclusion

This paper provides an initial insight into the interplay of political measures, social distancing behavior, and their impact on COVID-19 case and death growth. The study, employing a panel analysis at the federal state level in Germany, reveals that both policy interventions and private behavioral adjustments have significantly contributed to the observed declines in COVID-19 case and death growth rates. The findings indicate that policy changes account for a considerable portion of the variations in social distancing behaviors, underscoring the importance of both governmental policies and accessible national health information as pivotal determinants of COVID-19 outcomes.

However, limitations in the data meant that only the effect of business closures could be reliably estimated, preventing a comprehensive understanding of the efficacy of NPIs. The analysis also highlights a degree of uncertainty regarding the specific impact of mask mandates due to a lack of cross-sectional variation, pointing to an area requiring further investigation.

It remains crucial to determine the effectiveness of political measures and to what extent they are needed if individuals also change their behavior without enforcement. This study's insights emphasize the significant role of informed and strategic policy-making, while also suggesting that further research is needed to fully comprehend the nuances and long-term impacts of various NPIs.

References

Amuedo-Dorantes, Catalina, Cristina Borra, Noelia Rivera-Garrido, and Almudena Sevilla. 2021. "Early adoption of non-pharmaceutical interventions and COVID-19 mortality." *Economics & Human Biology* 42:101003. ISSN: 1570-677X. https://doi.org/https://doi.org/10.1016/j.ehb.2021.101003. https://www.sciencedirect.com/science/article/pii/S1570677X21000277.

Authority for Health and Consumer Protection. 2020a. Accessed February 4, 2022. https://www.hamburg.de/allgemeinverfuegungen/13721232/allgemeinverfuegung-zur-eindaemmung-des-coronavirus-in-hamburg/.

———. 2020b. Accessed February 4, 2022. https://www.hamburg.de/allgemeinverfuegungen/13746326/2020-03-22-voruebergehende-kontaktbeschraenkungen//13746326/2020-03-22-voruebergehende-kontaktbeschraenkungen/.

Authority for Labor, Health, Social Affairs, Family and Integration. 2020. Accessed March 3, 2021. https://www.luewu.de/gvbl/.

Bavarian State Government. 2022. Accessed February 7, 2022. https://www.bayern.de/staatsregierung/ministerpraesident/.

Bavarian State Ministry for Health and Care. 2022. Accessed January 4, 2022. https://www.verkuendung-bayern.de/baymbl/?offset=136%5C&ressort=12%5C&publicationType=sonstige_bekanntmachung#page-browser.

Berlin State Centre for Political Education. 2022. Accessed February 7, 2022. https://www.berlin.de/politische-bildung/politikportal/politik-in-berlin/wahlen-und-direkte-demokratie/wahlergebnisse-im-wandel/.

Bo, Yacong, Cui Guo, Changqing Lin, Yiqian Zeng, Hao Bi Li, Yumiao Zhang, Md Shakhaoat Hossain, et al. 2021. "Effectiveness of non-pharmaceutical interventions on COVID-19 transmission in 190 countries from 23 January to 13 April 2020." *International Journal of Infectious Diseases* 102. https://www.ijidonline.com/article/S1201-9712(20)32270-0/fulltext.

Brandenburg State Portal. 2022. Accessed February 7, 2022. https://www.brandenburg.de/sixcms/detail.php?id=bb1.c.594772.de.

Chan, Louis Yat Hin, Baoyin Yuan, and Matteo Convertino. 2021. "COVID-19 non-pharmaceutical intervention portfolio effectiveness and risk communication predominance." *Scientific Reports* 11 (10605). https://www.nature.com/articles/s41598-021-88309-1.

Chernozhukov, Victor, Hiroyuki Kasahara, and Paul Schrimpf. 2021. "Causal impact of masks, policies, behavior on early covid-19 pandemic in the U.S." Pandemic Econometrics, *Journal of Econometrics* 220 (1): 23–62. ISSN: 0304-4076. https://doi.org/https://doi.org/10.1016/j.jeconom.2020.09.003. https://www.sciencedirect.com/science/article/pii/S0304407620303468.

Country Portal of Mecklenburg-Western Pomerania. 2022. Accessed February 7, 2022. https://www.mecklenburg-vorpommern.de/ueber-das-land-zum-leben/land-und-regierung.

dpa-infocom GmbH. 2020. Accessed March 13, 2020. https://www.welt.de/newsticker/dpa_nt/infoline_nt/eilmeldungen/article206537101/Rheinland-Pfalz-schliesst-ab-Montag-alle-Schulen-und-Kitas.html.

Duhon, Jacqueline, Nicola Bragazzi, and Jude Dzevela Kong. 2021. "The impact of non-pharmaceutical interventions, demographic, social, and climatic factors on the initial growth rate of COVID-19: A cross-country study." *Science of the Total Environment* 760. https://www.sciencedirect.com/science/article/pii/S0048969720378566?via%5C%3Dihub.

Ebrahim, Senan, Henry Ashworth, Cray Noah, Adesh Kadambi, Asmae Toumi, and Jagpreet Chhatwal. 2020. "Reduction of COVID-19 Incidence and Nonpharmacologic Interventions: Analysis Using a US County–Level Policy Data Set." *Journal of Medical Internet Research* 22 (12). https://www.jmir.org/2020/12/e24614/.

Esra, Rachel, Lise Jamieson, Matthew P. Fox, Daniel Letswalo, Nkosinathi Ngcobo, Sithabile Mngadi, Janne Estill, Gesine Meyer-Rath, and Olivia Keiser. 2020. "Evaluating the impact of non-pharmaceutical interventions for SARS-CoV-2 on a global scale," https://www.medrxiv.org/content/10.1101/2020.07.30.20164939v1.

Federal Statistical Office of Germany (Destatis). 2020. Accessed September 8, 2021. https://www.destatis.de/DE/Themen/Laender-Regionen/Regionales/Gemeindeverzeichnis/Administrativ/02-bundeslaender.html.

———. 2022. Accessed February 2, 2022. https://www-genesis.destatis.de/genesis//online?operation=table%5C&code=13211-0012%5C&bypass=true%5C&levelindex=0%5C&levelid=1643820172207#abreadcrumb.

focus.de. 2020. Accessed December 29, 2020. https://www.focus.de/familie/eltern/familie-heute/nach-weihnachtsferien-distanzlernen-oder-praesenzunterricht-was-in-ihrem-bundesland-gilt_id_12651207.html.

Google. 2020. Accessed January 6, 2021. https://www.google.com/covid19/mobility/.

———. 2021. Accessed January 18, 2022. https://www.google.com/covid19/mobility/.

Google. 2022. Accessed February 17, 2022. https://support.google.com/covid19-mobility/answer/9824897?hl=en#zippy=.

Government of the Saarland. 2022. Accessed January 3, 2022. https://www.saarland.de/DE/portale/corona/service/rechtsverordnung-massnahmen/rechtsverordnung-massnahmen_node.html.

Government of the State Baden-Württemberg. 2022. Accessed January 4, 2022. https://www.baden-wuerttemberg.de/de/service/aktuelle-infos-zu-corona/aktuelle-corona-verordnung-des-landes-baden-wuerttemberg/.

Hesse. 2020. Accessed January 4, 2022. https://www.rv.hessenrecht.hessen.de/bshe/search.

Hesse State Government. 2022. Accessed February 7, 2022. https://www.hessen.de/Regierung/Ministerpraesident/Lebenslauf-des-Ministerpraesidenten.

Hessian Cabinet. 2021. Accessed January 4, 2022. https://www.hessen.de/Handeln/Corona-in-Hessenhttps://www.hessen.de/Handeln/Corona-in-Hessen/Corona-Meldungen-2021.

Islam, Nazrul, Stephen J. Sharp, Gerardo Chowell, Sharmin Shabnam, Ichiro Kawachi, Ben Lacey, Joseph M. Massaro, Ralph B. D'Agostino Sr, and Martin White. 2020. "Physical distancing interventions and incidence of coronavirus disease 2019: natural experiment in 149 countries." *BMJ* 370. https://www.bmj.com/content/370/bmj.m2743.

Jalali, Aliea M., Sumaia G. Khoury, JongWon See, Alexis M. Gulsvig, Brent M. Peterson, Richard S. Gunasekera, Gentian Buzi, Jason Wilson, and Thushara Galbadage. 2020. "Delayed Interventions, Low Compliance, and Health Disparities Amplified the Early Spread of COVID-19." *medRxiv,* https://www.medrxiv.org/content/10.1101/2020.07.31.20165654v1.full-text.

Karaivanov, Alexander, Shih En Lu, Hitoshi Shigeoka, Cong Chen, and Stephanie Pamplona. 2020. "Face masks, public policies and slowing the spread of COVID-19: Evidence from Canada." *Working Paper* 27891. http://www.nber.org/papers/w27891.

Kovacs, Roxanne, Maurice Dunaiski, and Janne Tukiainen. 2020. "Compulsory Face Mask Policies Do not Affect Community Mobility in Germany." *SSRN,* https://doi.org/http://dx.doi.org/10.2139/ssrn.3620070. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3620070.

Landesportal Schleswig-Holstein. 2020a. Accessed February 4, 2022. https://www.schleswig-holstein.de/DE/Landesregierung/III/_startseite/Artikel_2020/03_Maerz/200313_schulausfaelle_corona.html.

———. 2020b. Accessed April 16, 2020. https://www.schleswig-holstein.de/DE/Landesregierung/III/_startseite/Artikel_2020/04_April/200416_statement_corona.html.

Landesportal Schleswig-Holstein. 2021. Accessed February 4, 2022. https://www.schleswig-holstein.de/DE/Schwerpunkte/Coronavirus/Schulen_Hochschulen/corona_schule.html#docb5a355f7-c9fa-4b6d-86f9-452954b9875%20abodyText6.

Liu, Yang, Christian Morgenstern, James Kelly, Rachel Lowe, CMMID COVID-19 Working Group, and Mark Jit. 2021. "The impact of non-pharmaceutical interventions on SARS-CoV-2 transmission across 130 countries and territories." *BMC Medicine* 19 (40). https://bmcmedicine.biomedcentral.com/articles/10.1186/s12916-020-01872-8.

Lower Saxony Ministry of Social Affairs, Health and Equality. 2020. Accessed April 2, 2022. https://www.niedersachsen.de/politik_staat/gesetze_verordnungen_und_sonstige_vorschriften/verkundungsblatter_vorjahre/verkundungsblatter_vorjahre/niedersachsisches-gesetz-und-verordnungsblatt-2020-195982.html.

Minister for Education, Science and Culture and Prime Minister and Minister for Social Affairs, Health, Youth Family and Seniors. 2021. Accessed January 3, 2022. https://www.schleswig-holstein.de/DE/Landesregierung/IV/Service/GVOBl/gvobl_node.html.

Minister for Social Affairs, Health, Youth Family and Seniors. 2020. Accessed April 2, 2022. https://transparenz.schleswig-holstein.de/dataset/c7520068-ca12-43f1-9cd8-39c20091418b.

Minister of Labor, Heath and Social Affairs of the State of North Rhine-Westphalia. 2022. Accessed January 3, 2022. https://www.land.nrw/mediathek?search=%5C&sort_by=search_api_relevance%5C&start_date=%5C&end_date=%5C&items_per_page=60%5C&page=0.

Minister of Social Affairs, Health and Sport. 2022. Accessed January 5, 2022. https://www.regierung-mv.de/Landesregierung/jm/service_justizministerium/verkuendungsblaetter/gesetz-verordnungsblaetter.

Minister of Social Affairs, Labor, Health and Demography. 2021. Accessed January 3, 2021. https://corona.rlp.de/de/service/rechtsgrundlagen/.

Ministry of Labor, Social Affairs, Health, Women and Family Affairs. 2022. Accessed January 3, 2022. https://www.tmasgff.de/covid-19/rechtsgrundlage.

Ministry of Lower Saxony for Social Affairs, Health and Equality. 2021. Accessed January 4, 2022. https://www.niedersachsen.de/Coronavirus/aktuelle-presseinformationen-186247.html.

Ministry of Social Affairs, Health, Integration and Consumer Protection of the State of Brandenburg. 2022. Accessed January 4, 2022. https://msgiv.brandenburg.de/msgiv/de/coronavirus/informationen-zum-coronavirus-sars-cov-2/archiv-corona-verordnungen/.

Niedersächsisches Kultusministerium. 2020. Accessed February 4, 2022. https://www.niedersachsen.de/Coronavirus/schule-in-corona-zeiten-so-setzt-niedersachsen-den-unterricht-nach-den-herbstferien-fort-185451.html.

Pieper, Jonas, Ulrich Schneider, and Wiebke Schröder. 2020. "Money helps against poverty. The Paritätische Poverty Report 2020." Edited by Deutscher Paritätische Gesamtverband e. V. Accessed February 4, 2022. https://www.der-paritaetische.de/fileadmin/user_upload/Publikationen/doc/broschuere_armutsbericht-2020_web.pdf.

Pleninger, Regina, Sina Streicher, and Jan-Egbert Sturm. 2022. "Do COVID-19 containment measures work? Evidence from Switzerland." *Swiss Journal of Economics and Statistics* 158 (5). https://sjes.springeropen.com/articles/10.1186/s41937-022-00083-7.

Robert Koch Institut. 2020. Accessed December 14, 2020. https://survstat.rki.de/Content/Query/Create.aspx.

———. 2022. Accessed January 18, 2022. https://www.rki.de/DE/Content/InfAZ/N/Neuartiges_Coronavirus/Situationsberichte/Gesamt.html;jsessionid=81752764B%209CAC4B250930436EFAB12E7.internet062?nn=13490888.

Saxon State Ministry for Social Affairs and Social Cohesion. 2022. Accessed January 3, 2022. https://www.coronavirus.sachsen.de/archiv-der-abgelaufenen-amtlichen-bekanntmachungen-7295.html.

Saxony-Anhalt State Portal. 2022. Accessed February 7, 2022. https://www.sachsen-anhalt.de/lj/politik-und-verwaltung/ministerpraesident/amt-des-ministerpraesidenten/.

Schleswig-Holstein State Portal. 2022. Accessed February 7, 2022. https://www.schleswig-holstein.de/DE/Landesregierung/landesregierung_node.html.

Senate of Berlin. 2022. Accessed January 4, 2022. https://pardok.parlament-berlin.de/portala/browse.tt.html.

Senate of Hamburg. 2022. Accessed January 4, 2022. https://www.hamburg.de/pressearchiv/.

Senate Office of Hamburg. 2022. Accessed February 7, 2022. https://www.hamburg.de/buergermeister-hamburg/.

Senator for Health, Women and Consumer Protection. 2022. Accessed January 4, 2022. https://www.gesetzblatt.bremen.de/gesetzblatt-1459?submit=suchen%5C&sv%5C%5Bsuchbegriff%5C%5D=Coronaverordnung&sv%5C%5Bsuchbegriff_jahr%5C%5D%5C%5B0%5C%5D=0&sv%5C%5Bsuchbegriff_jahr%5C%5D%5C%5B1%5C%5D=0.

Siedner, Mark J., Guy Harling, Zahra Reynolds, Rebecca F. Gilbert, Sebastien Haneuse, Atheendar S. Venkataramani, and Alexander C. Tsai. 2020. "Social distancing to slow the US COVID-19 epidemic: Longitudinal pretest–posttest comparison group study." *PLoS Medicine* 17 (8). https://journals.plos.org/plosmedicine/article?id=10.1371/journal.pmed.1003244.

State Chancellery of Lower Saxony. 2022. Accessed February 7, 2022. https://www.stk.niedersachsen.de/startseite/der_ministerprasident/die-niedersaechsischen-ministerprae%20sidenten-3401.html.

State Chancellery of Saarland. 2022. Accessed February 7, 2022. https://www.saarland.de/stk/DE/institution/mp/mp_node.html.

State Chancellery of Saxony. 2022. Accessed February 7, 2022. https://www.ministerprae%20sident.sachsen.de/biografie-des-ministerpraesidenten-3407.html.

State Chancellery Unesco World Heritage City Hall of Bremen. 2022. Accessed February 7, 2022. https://www.rathaus.bremen.de/senate-ab-1945-61069#2019.

State Gorvernment of Saxony-Anhalt. 2022. Accessed January 3, 2022. https://ms.sachsen-anhalt.de/themen/gesundheit/aktuell/coronavirus/verordnungen-erlasse-und-empfehlungen/.

State Government of North Rhine-Westphalia. 2022. Accessed February 7, 2022. https://www.land.nrw/ministerpraesidenten-seit-1946.

State Government of Rhineland-Palatinate. 2020. Accessed February 4, 2022. https://corona.rlp.de/de/aktuelles/detail/news/News/detail/zukunftsperspektive-rheinland-pfalz-theater-konzerthaeuser-und-kinos-koennen-ab-27-mai-wieder-oeffne-1/.

———. 2022. Accessed February 7, 2022. https://www.rlp.de/de/regierung/ministerpraesidentin-malu-dreyer/ministerpraesidenten-von-rheinland-pfalz/.

State Government of Thuringia. 2022. Accessed February 7, 2022. https://www.landesregierung-thueringen.de/mp/mp/.

State Ministry of Baden-Württemberg. 2022. Accessed February 7, 2022. https://www.baden-wuerttemberg.de/de/regierung/ministerpraesident/ministerpraesidenten-seit-1952/.

Wang, Feng, Xing Ge, and Danwen Huang. 2022. "Government Intervention, Human Mobility, and COVID-19: A Causal Pathway Analysis from 121 Countries." *Sustainability* 14 (6). https://www.mdpi.com/2071-1050/14/6/3694.

Wheaton, William C, and Anne Kinsella Thompson. 2020. "The geography of COVID-19 growth in the US: Counties and metropolitan areas." *Available at SSRN 3570540.*

ZDFheute. 2020. Accessed February 4, 2022. https://www.zdf.de/nachrichten/heute/niedersachsen-corona-schulen-geschlossen-100.html.