UNIVERSITÄT SIEGEN

What factors affect excess mortality?

Research Seminar Markets & Strategies II

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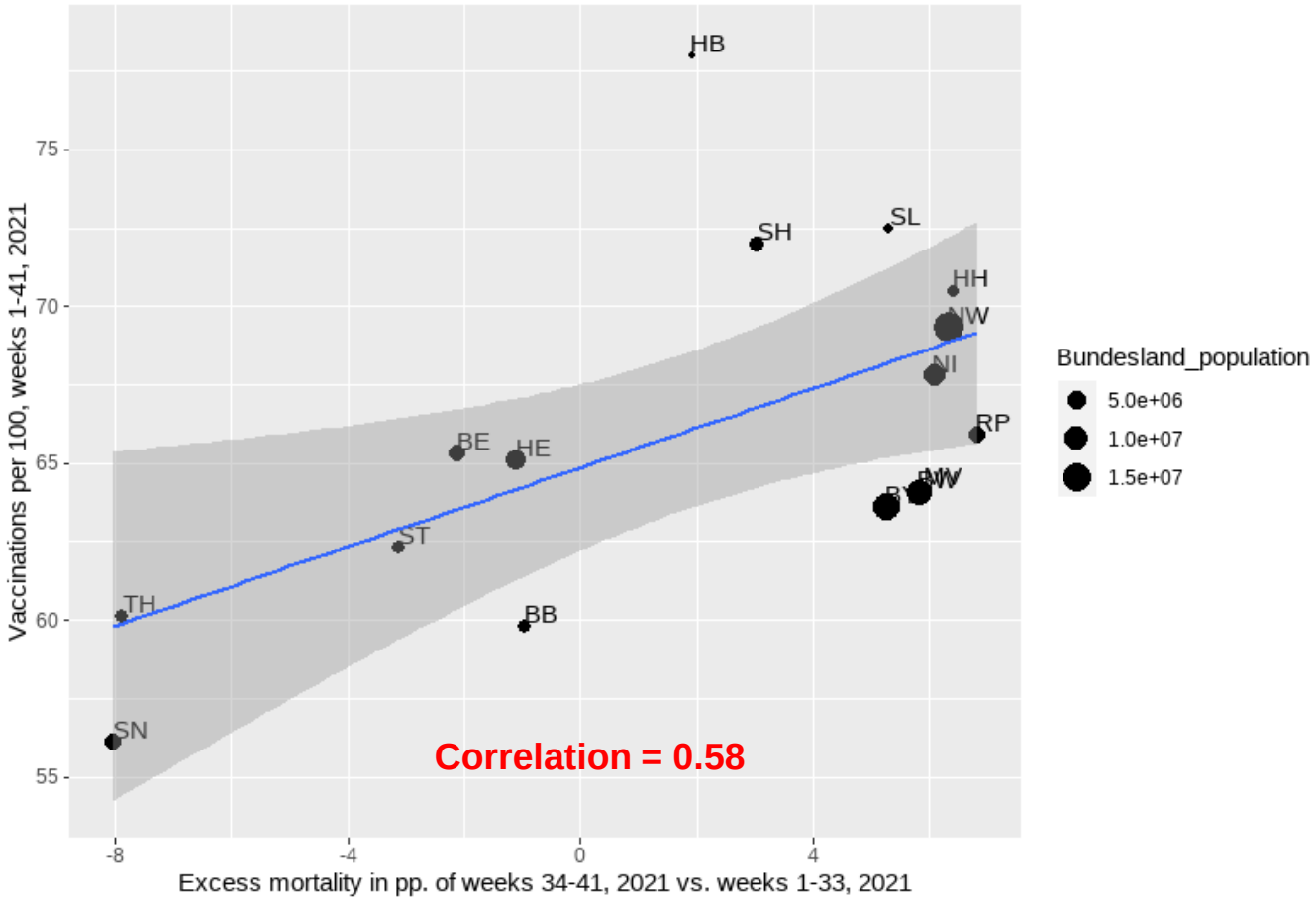
Motivation

Correlation between change in Excess mortality and the vaccination rate



On 20.11.2021 Mr. Thorsten Wiethölter claimed in his article:

- *„The higher the vaccination rate, the higher the excess mortality"* referring to the correlation numbers.

How was it calculated? →

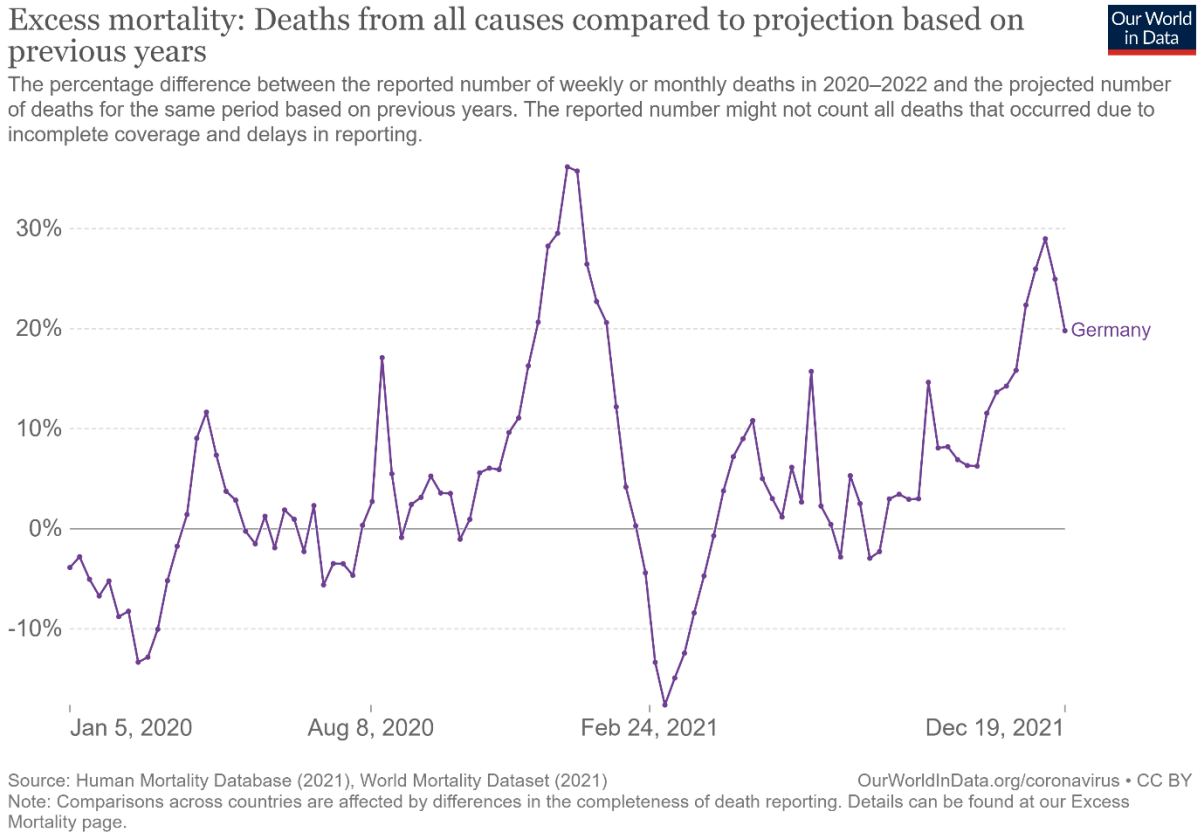
- **Diff. in Excess mortality in pp**. between weeks 34-41, 2021 and weeks 1-33, 2021 by Bundeslands was **set against the fully vaccinated people per 100** in weeks 1-41, 2021
- Excess mortality = Mortality 2021/ Average Mortality 2016-2020

→ Does the vaccination increase the excess mortality?

Source: https://coronakriseblog.wordpress.com/2021/11/20/impfquoten-und-ubersterblichkeit-in-deutschen-bundeslandern/

Research Question

What factors can explain the excess mortality in Germany during COVID-19?



Empirical Strategy

I. COLLECT, AGGREGATE, ENRICH and CLEAN THE DATA

=>

- Data by weeks from COVID-19 start are available on the following levels:
  - ✓ County – 38 095 observations
  - ✓ Bundesland – 2 618 observations
  - ✓ Germany – 208 observations
- Time dimension:
  - ✓ 10th week 2020 – 43th week 2021

**Please refer to the "Additional note" file for the comments on variables*

Empirical Strategy

II. INVESTIGATE THE DATA QUALITY and COMPLETENESS

County level

+ the highest amount of observations
- no data on mortality
- not reliable data on the vaccinations
- no possibility to introduce the age

Bundesland level

+ large amount of observations
- mismatch of the age groups in different data sets
- no possibility to control for demographics change

Germany level

+ the most complete data
- small amount of observations

=> BUNDESLAND and GERMANY LEVELS OF DATA ALLOW TO CONTROL FOR MORE VARIABLES

Empirical Strategy

III. INTRODUCE THE MAIN DEFINITIONS

- Dependent variable

EXCESS MORTALITY	EXCESS MORTALITY ACCOUNTING FOR DEMOGRAPHICS
number of people died in particular week during COVID-19 / average number of people died in 2016-2019 in bundesland i in period t	*number of actual deaths / number of forecasted deaths in Germany in period t in particular age group*
Available at Bundesland and Germany level	Available at Germany level only, allows to account for demographical shift in the age groups over the years

**Please refer to the "Additional note" file for more information on excess mortality calculation*

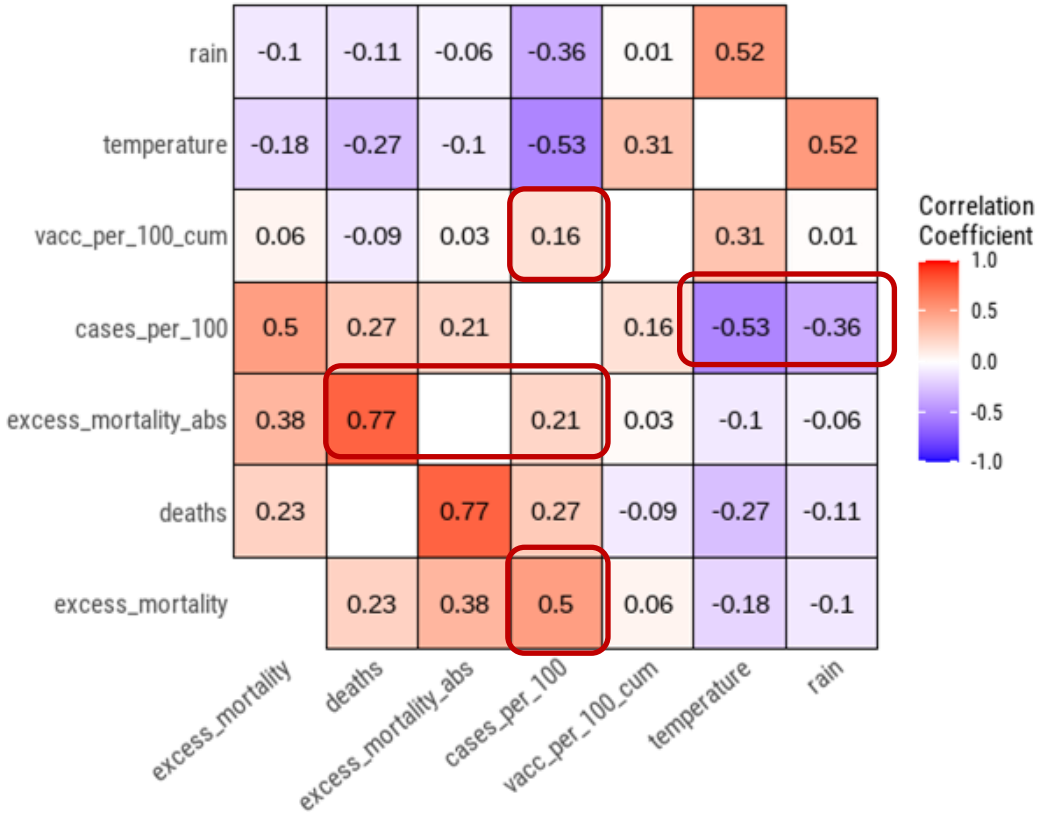
- Independent variables

VACCINATIONS	COVID-19 CASES	AGE GROUP
TEMPERATURE	RAIN	

Empirical Strategy

IV. EXPLORE THE DATA

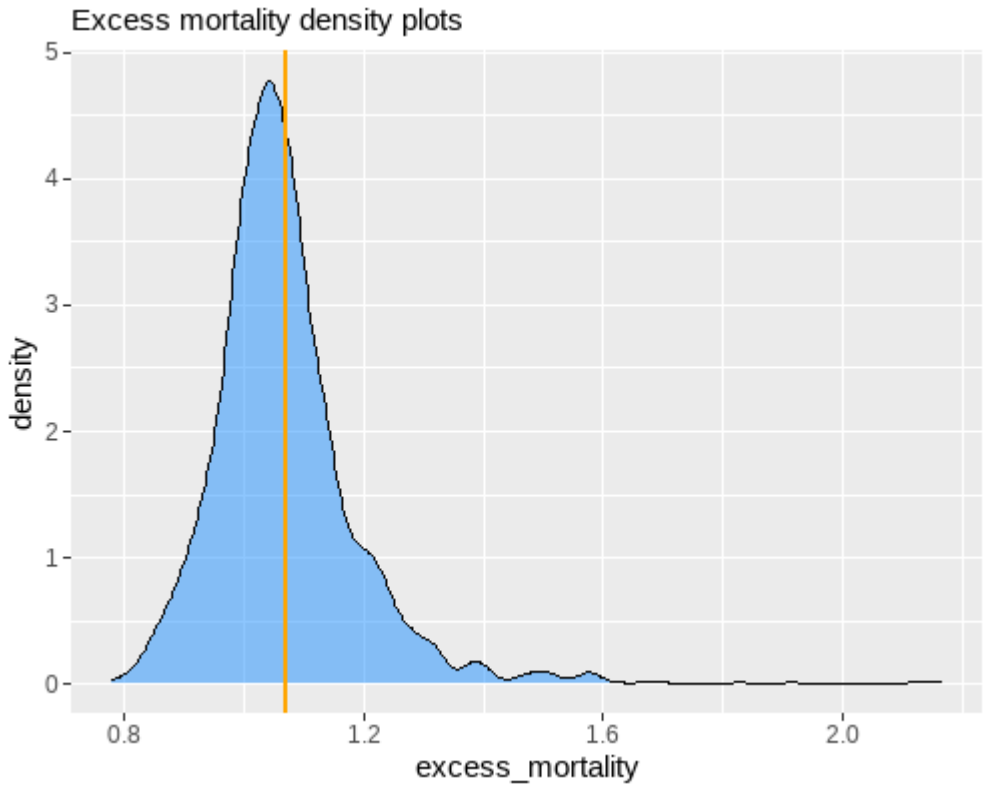
- Correlation matrix of the key variables indicates:
  - Excess mortality strongly correlates with COVID-19 cases and COVID-19 deaths
  - COVID-19 cases per 100 negatively correlate with temperature and rain
  - There is a positive correlation of vaccination rate per 100 and COVID-19 cases per 100

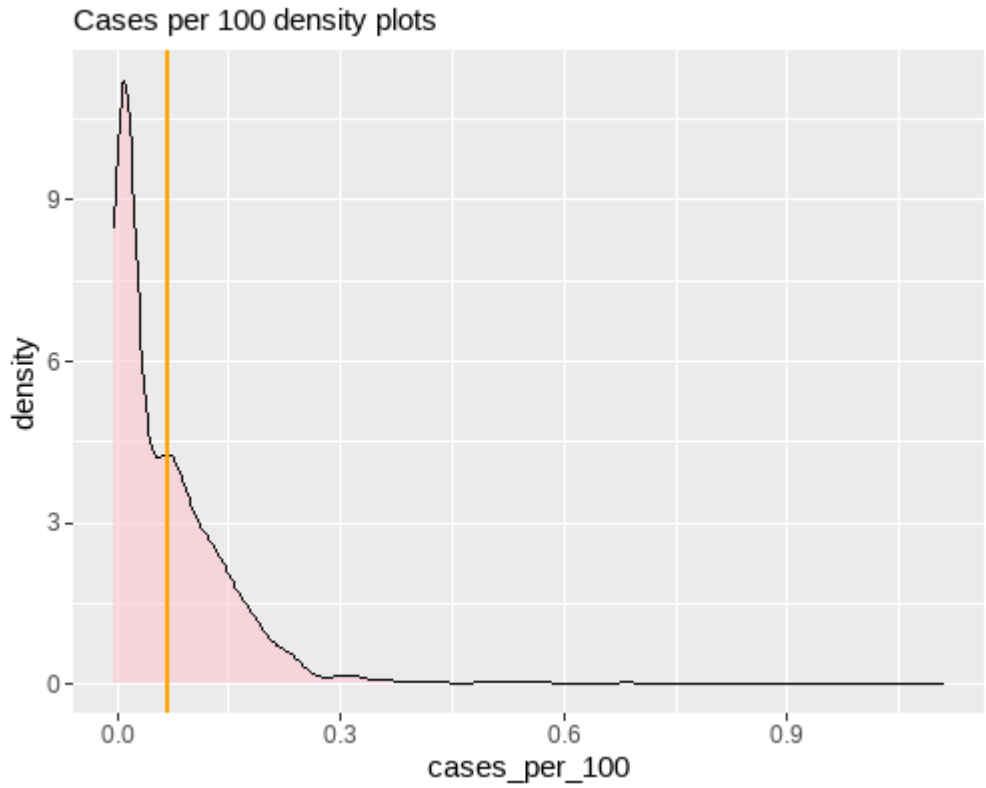


Empirical Strategy

IV. EXPLORE THE DATA

- Excess mortality and COVID-19 cases per 100 are normally distributed with long tail





Period: 10th week 2020 – 43th week 2021

Empirical Strategy

V. ASSUMPTIONS

- The age structure and population of 2021 is the same as in 2020. The demographic data for 2021 were not available at the time of research.
- Mid-year age structure and population is a good proxy for weekly age structure and population.
- Temperature and rain variation within a Bundesland is low.

Model (1): Bundesland level

LINEAR MODEL WITH INTERACTION TERM

$$exc\_mortality_{itk} = \beta_0 + \beta_1\, vacc\_per\_100\_cum_{itk} + \gamma\, cases\_per\_100_{itk-l} + \delta\, age\_group\_60 + \varepsilon\, bundesland_i + \alpha_1\, temperature_{it} + \alpha_2\, rain_{it} + \theta\, cases\_per\_100_{itk} * age\_group\_60 + \epsilon_{itk} \quad (1)$$

- Variables:
  - $exc\_mortality_{itk}$ = mortality in COVID-19 period / average of mortality in 2016-2019 in bundesland i in period t of the age group k
  - $vacc\_per\_100\_cum_{itk}$ = cumulative number of fully vaccinated people (amount of vaccines = 2) per 100 in bundesland i in period t of the age group k
  - $cases\_per\_100_{itk-l}$ = number of COVID-19 confirmed cases per 100 in bundesland i in period t of the age group k, l stands for lag values of COVID-19 cases with $l \in [0, 4]$
  - age_group_60 = dummy variable, equal to 1, if people are older than 60
  - $bundesland_i$ = dummy variable for bundesland i
  - $cases\_per\_100_{itk} * age\_group\_60$ = interaction term of age dummy and cases per 100
  - $temperature_{it}$ = average temperature in bundesland i in period t
  - $rain_{it}$ = average rain l/m² in bundesland i in period t

**Please refer to the "Additional note" file for the comments on variables*

Model (2): Germany level

LINEAR MODEL WITH INTERACTION TERM

$$exc\_mortality_{tk} = \beta_0 + \beta_1\, vacc\_per\_100\_cum_{tk} + \gamma\, cases\_per\_100_{tk-l} +$$

$$\delta\, age\_group\_60 + \alpha_1\, temperature_t + \alpha_2\, rain_t + \theta\, cases\_per\_100_{tk} * age\_group\_60 + \epsilon_{tk} \quad (4)$$

- Variables:
  - $exc\_mortality_{kt}$ = mortality in COVID-19 period / average of mortality in 2016-2019 in period t of the age group k
  - $vacc\_per\_100\_cum_{kt}$ = cumulative number of fully vaccinated people (amount of vaccine = 2) per 100 in period t of the age group k
  - $cases\_per\_100_{kt}$ = number of COVID-19 confirmed cases per 100 in period t of the age group k, , l stands for lag values of mortality with $l \in [0, 4]$
  - age_group_60 = dummy variable, equal to 1, if people are older than 60
  - $temperature_t$ = average temperature in Germany in period t
  - $rain_t$ = average rain l/m² in Germany in period t

**Please refer to the "Additional note" file for the comments on variables*

Model (3): Germany level

LINEAR MODEL WITH INTERACTION TERM AND DEMOGRAPHIC CHANGE IN MORTALITY

$$exc\_mortality\_demo_{tk} = \beta_0 + \beta_1\, vacc\_per\_100\_cum_{tk} + \gamma\, cases\_per\_100_{tk-l} +$$

$$\delta\, age\_group\_60 + \theta\, cases\_per\_100_{tk} * age\_group\_60 + \epsilon_{tk} \quad (5)$$

- Variables:
  - $exc\_mortality\_demo_{tk}$ = number of actual deaths / number of forecasted deaths in Germany in period t of the age group k
  - $vacc\_per\_100\_cum_{kt}$ = cumulative number of fully vaccinated people (amount of vaccine = 2) per 100 in period t of the age group k
  - $cases\_per\_100_{kt}$ = number of COVID-19 confirmed cases per 100 in period t of the age group k, l stands for lag values of mortality with $l \in [0, 4]$
  - age_group_60 = dummy variable, equal to 1, if people are older than 60
  - $temperature_t$ = average temperature in Germany in period t
  - $rain_t$ = average rain l/m² in Germany in period t

**Please refer to the "Additional note" file for the comments on variables*

Results

	Dependent variable:		
	exc_mortality		exc_mortality_demo
	(1)	(2)	(3)
vacc_per_100_cum	-0.0003	-0.0002	-0.0002
	(0.0002)	(0.0004)	(0.0004)
cases_per_100	0.760***	0.550***	0.548***
	(0.078)	(0.196)	(0.192)
age_group60+	0.028***	0.070***	0.027*
	(0.006)	(0.015)	(0.015)
temperature	0.005***	0.004**	0.004**
	(0.001)	(0.002)	(0.002)
rain	0.00000	-0.0002	-0.0002
	(0.0001)	(0.0002)	(0.0002)
cases_per_100:age_group60+	5.824***	4.107***	3.965***
	(0.344)	(0.859)	(0.839)
Constant	0.899***	0.919***	0.929***
	(0.015)	(0.028)	(0.027)
Observations	2,618	154	154
R2	0.393	0.430	0.275
Adjusted R2	0.388	0.407	0.245
Residual Std. Error	0.122 (df = 2595)	0.065 (df = 147)	0.064 (df = 147)
F Statistic	76.516*** (df = 22; 2595)	18.497*** (df = 6; 147)	9.273*** (df = 6; 147)

Note: *p<0.1; **p<0.05; ***p<0.01

Results interpretation

	Dependent variable:	
	exc_mortality (1)	st.dev.
vacc_per_100_cum	-0.0003 (0.0002)	12.87
cases_per_100	0.760*** (0.078)	0.04
age_group60+	0.028*** (0.006)	0.5
temperature	0.005*** (0.001)	5.38
rain	0.00000 (0.0001)	32.64
cases_per_100:age_group60+	5.824*** (0.344)	0.0095
Constant	0.899*** (0.015)	
Observations	2,618	
R2	0.393	
Adjusted R2	0.388	
Residual Std. Error	0.122 (df = 2595)	
F Statistic	76.516*** (df = 22; 2595)	
Note:	*p<0.1; **p<0.05; ***p<0.01	

Level – level model (1):

- increase in $vacc\_per\_100\_cum$ **by 1** leads to -**0.0003 pp.** decrease in $exc\_mortality$. The coefficient is neither statistically nor economically significant;
- increase in $cases\_per\_100$ **by 1** leads to **0.760 pp.** increase in $exc\_mortality$. The coefficient is significant at 1% level;
- dummy age_group_60 + **equal 1** increases intercept of $exc\_mortality$ by **0.028 pp**. The coefficient is significant at 1% level;
- Increase in $temperature$ **by 1** lease to **0.005 pp**. increase in $exc\_mortality$. The coefficient is significant at 1% level;
- $rain$ has no effect on excess mortality
- increase in $cases\_per\_100$ within the age_group_60 + **by 1** leads to **5.824** pp. increase in $exc\_mortality$**.** The coefficient is significant at 1% level.

If all statistically significant coefficients will increase by 1 standard deviation $exc\_mortality$ will be:

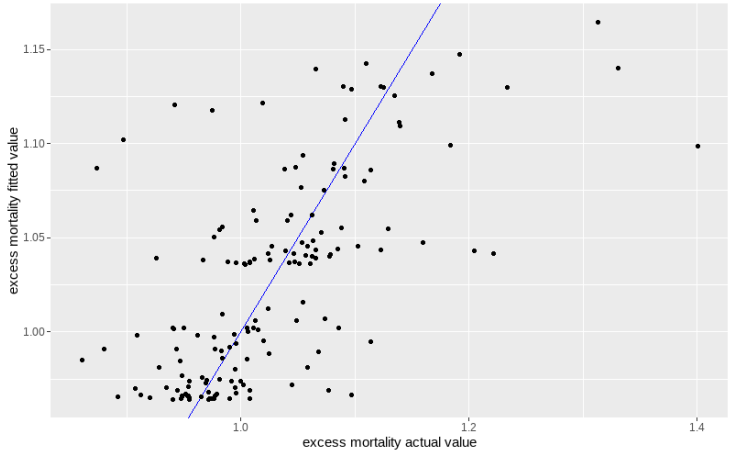
- $\mathbf{0.899} + \mathbf{0.760} * 0.04 + \mathbf{0.028} * 0.05 + \mathbf{0.005} * 5.38 + \mathbf{5.824} * 0.0095 = 0.899 + 0.0304 + 0.014 + 0.0269 + 0.0553 = \mathbf{1.0256}$

→ **2.56% excess mortality**

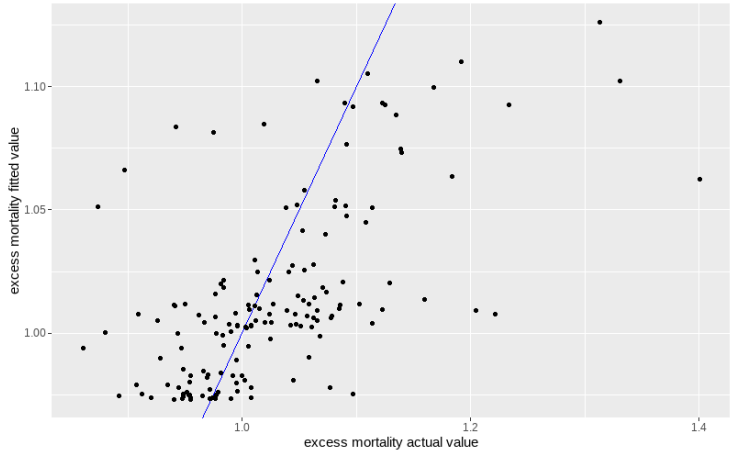
Results: actual vs. fitted values

MODEL (1)

MODEL (2)



MODEL (3



- Prediction errors seem to be of similar size and randomly distributed along the whole value range in all models
- x-axis – actual value, y-axis – fitted value

Robustness check: COVID-19 cases with lags (1)

- **Model 1 – basic model without lags on Bundesland level, Models 2-5 – Bundesland level with different lags**

	Dependent variable:				
	exc_mortality				
	(1)	(2)	(3)	(4)	(5)
vacc_per_100_cum	-0.0003	0.0002	-0.0001	0.0005**	0.0005**
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
cases_per_100	0.760***				
	(0.078)				
cases_per_100_lag_1_week		0.557***			
		(0.078)			
cases_per_100_lag_2_weeks			0.797***		
			(0.081)		
cases_per_100_lag_3_weeks				0.280***	
				0.081)	
cases_per_100_lag_4_weeks					0.247***
					(0.083)
age_group60+	0.028***	0.050***	0.033***	0.053***	0.051***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.007)
temperature	0.005***	0.002**	0.005***	-0.001	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
rain	0.00000	0.00002	-0.00001	0.00000	-0.00005
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
cases_per_100:age_group60+	5.824***				
	(0.344)				
cases_per_100_lag_1_week:age_group60+		2.296***			
		(0.218)			
cases_per_100_lag_2_weeks:age_group60+			5.731***		
			(0.360)		
cases_per_100_lag_3_weeks:age_group60+				1.484***	
				(0.228)	
cases_per_100_lag_4_weeks:age_group60+					2.124***
					(0.375)
Constant	0.899***	0.906***	0.902***	0.966***	0.998***
	(0.015)	(0.016)	(0.015)	(0.016)	(0.016)
Observations	2,618	2,584	2,550	2,516	2,482
R2	0.393	0.369	0.396	0.343	0.339
Adjusted R2	0.388	0.363	0.391	0.337	0.333
Residual Std. Error	0.122 (df = 2595)	0.125 (df = 2561)	0.122 (df = 2527)	0.128 (df = 2493)	0.129 (df = 2459)
F Statistic	76.516*** (df = 22; 2595)	67.996*** (df = 22; 2561)	75.442*** (df = 22; 2527)	59.080*** (df = 22; 2493)	57.229*** (df = 22; 2459)

Please refer to the "Additional note" file for the comments on the results

Robustness check: COVID-19 cases with lags (2)

- **Model 3 – basic model without lags on Germany level accounting for demographic shift, Models 2-5 – Germany level with different lags**

	Dependent variable:				
	exc_mortality_demo				
	(1)	(2)	(3)	(4)	(5)
vacc_per_100_cum	-0.0002	-0.0002	-0.0003	-0.0002	-0.0002
	(0.0004)	(0.0004)	(0.0004)	(0.0004)	(0.0004)
cases_per_100	0.548***				
	(0.192)				
cases_per_100_lag_1_week		2.865***			
		(0.928)			
cases_per_100_lag_2_weeks			0.709***		
			(0.198)		
cases_per_100_lag_3_weeks				3.166***	
				(0.960)	
cases_per_100_lag_4_weeks					0.642***
					(0.218)
age_group60+	0.027*	0.031**	0.025*	0.024*	0.028*
	(0.015)	(0.014)	(0.014)	(0.014)	(0.015)
temperature	0.004**	0.004**	0.005***	0.005**	0.005**
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
rain	-0.0002	-0.0001	-0.0002	-0.0002	-0.0002
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
cases_per_100:age_group60+	3.965***				
	(0.839)				
cases_per_100_lag_1_week:age_group60+		-1.931**			
		(0.860)			
cases_per_100_lag_2_weeks:age_group60+			4.895***		
			(0.855)		
cases_per_100_lag_3_weeks:age_group60+				-1.995**	
				(0.874)	
cases_per_100_lag_4_weeks:age_group60+					4.411***
					(0.934)
Constant	0.929***	0.928***	0.909***	0.914***	0.921***
	(0.027)	(0.028)	(0.028)	(0.030)	(0.032)
Observations	154	152	150	148	146
R2	0.275	0.279	0.338	0.328	0.298
Adjusted R2	0.245	0.249	0.310	0.299	0.267
Residual Std. Error	0.064 (df = 147)	0.063 (df = 145)	0.060 (df = 143)	0.061 (df = 141)	0.062 (df = 139)
F Statistic	9.273*** (df = 6; 147)	9.346*** (df = 6; 145)	12.154*** (df = 6; 143)	11.473*** (df = 6; 141)	9.821*** (df = 6; 139)

Please refer to the "Additional note" file for the results comment

Conclusions

- In order to understand, what factors influence excessive mortality other than vaccination I collected the weekly data from COVID-19 start in 2020 till 43th week 2021 on Bundesland and Germany level.
- The main result indicates that **Excess Mortality** can be primarily explained by **COVID-19 cases, Age** and **Temperature**, while the coefficients for **Vaccination rate** are neither economicaly nor statistically significant. The result robustness is confirmed by different model specifications with various lag values of the variable COVID-19 cases.
- → When controlled for other factors, there is **no positive relationship between the Vaccination rate and Excess mortality**. The other question is why there is no negative relationship? The possible explanations are:
  - It is unknown whether excess deaths occured among vaccinated or not vaccinated individuals;
  - The relation between vaccination and excess mortality might be not linear.
- Another question for the further research might be the choice of the lag value for COVID-19 cases. My data indicate that the optimal value of lag ranges from 0 to 2, when the highest R-squared is achieved. However, it should be additionally investigated.

Thank you!

Appendix

Data sources

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1. Impfquoten und Übersterblichkeit in deutschen Bundesländern: https://coronakriseblog.wordpress.com/2021/11/20/impfquoten-und-ubersterblichkeit-in-deutschen-bundeslandern/
2. Destatis Sonderauswertung Todesfälle https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Bevoelkerung/Sterbefaelle-Lebenserwartung/Tabellen/sonderauswertung-sterbefaelle.html;jsessionid=5CEEE6B69887285095ADE798EBF52DFF.live712
3. RKI-Impfdaten https://github.com/robert-koch-institut/COVID-19-Impfungen_in_Deutschland
4. COVID-19 deaths and cases: https://github.com/jgehrcke/covid-19-germany-gae
5. Excess mortality due to COVID-19 in Germany https://www.sciencedirect.com/science/article/pii/S016344532030596X
6. Tracking excess mortality across countries during the COVID-19 pandemic with the World Mortality Dataset https://elifesciences.org/articles/69336
7. Temperature https://de.statista.com/statistik/daten/studie/5564/umfrage/monatliche-durchschnittstemperatur-in-deutschland/
8. Rain https://de.statista.com/statistik/daten/studie/576867/umfrage/durchschnittlicher-niederschlag-pro-monat-in-nordrhein-westfalen/
9. Temperature by Bundeslands https://www.wetterkontor.de/wetter-rueckblick/gebietsmittel/monatswerte/thueringen