



## BACKGROUND

Various model-based studies acknowledged the importance of mass vaccination strategies and NPIs in mitigating the spread of COVID-19.<sup>1-5</sup> Many studies showed the importance of simultaneously implementing vaccination and non-pharmaceutical interventions (NPIs). They mainly focused on timelines up until 2020 or 2021 and considered different types of NPIs.<sup>6,7</sup> Little is known about the relative effectiveness of COVID-19 vaccination and its interaction with non-pharmaceutical interventions (NPIs) in reducing infections, deaths, COVID-19 reproduction rate, and job losses.

## OBJECTIVE

To examine the relative effectiveness of vaccination and NPIs on COVID-19 infection, deaths, reproduction rate, and unemployment rate in the US.

## METHODS

- Data:**
- US national-level epidemiological and accompanying data obtained from "Our World in Data"<sup>8</sup>
  - Unemployment rate from the US Bureau of Labour Statistics<sup>9</sup>
  - Oxford Coronavirus Government Response Tracker (OxCGRT)<sup>10</sup>
  - Study period: January 2020 to February 2023.

- Data Analyses:**
- Quasi-experimental design approach, regression discontinuity design (RDD) in time
  - Empirical strategy:
 
$$Y_t = \beta_0 + \beta_1 1(treatment_t) + \beta_2 X_t + \epsilon_t$$
 where,  $Y_t$  = outcome variables of interest  
 treatment = an indicator variable  
 $X_t$  = a set of time-varying information  
 $\beta_1$  = effect of vaccination on outcome variables of interest

- Model estimated by using the ordinary least squares (OLS) method, considering different time windows.

## RESULTS

- Average number of reported daily cases was 46 million and average number of new cases and deaths per million per day were 271 and 3, respectively.
- On average, 450 million vaccine doses were administered, with 176 million people fully vaccinated.
- New cases and deaths per million spiked during each new year cycle. (Fig 1(A))
- Stringent measures were implemented at the beginning of the pandemic (stringency index=75) to contain the spread of the virus, and as the proportion of people fully vaccinated increased, the stringency index decreased steadily. (Fig 1(B))

### Descriptive Results

Table I: Descriptive statistics results of main epidemiological and response variables through January 2020 to February 2023

Variables	Mean	SD	Min	Max
<b>Epidemiological variables</b>				
Total Cases	46200000	36100000	1	103000000
Total Cases/million	136503.50	106578.100	0.003	304839.30
New cases/million	271.21	376.41	0	4003.96
Total deaths	638202.50	362086.40	1	1117497
Total deaths/million	1886.55	1070.34	0.003	3303.37
New deaths/million	3.05	2.740	0	13.03
Reproduction rate	1.08	0.39	0.52	3.61
ICU patients/million	30.83	23.22	4.23	85.40
<b>Policy variables</b>				
Stringency index	49.41	19.01	0	75.46
Total vaccinations	450000000	199000000	43553	671000000
People fully vaccinated	176000000	71200000	9223	230000000
Total boosters	53800000	53200000	1	133000000
New vaccinations	846083.30	850971.40	2426	4572363

### US unemployment during the pandemic

	5.61	2.70	3.40	14.70
Total unemployment rate	5.61	2.70	3.40	14.70
Men > 20 years old	5.28	2.41	3.10	13
Women > 20 years old	5.35	2.93	3.10	15.50
Whites	5.01	2.56	3	14.10
Black/African American	8.63	3.10	5.30	16.80
Asian	5.38	3.43	2.10	14.90
Hispanic or Latino	7.06	3.64	3.90	18.80

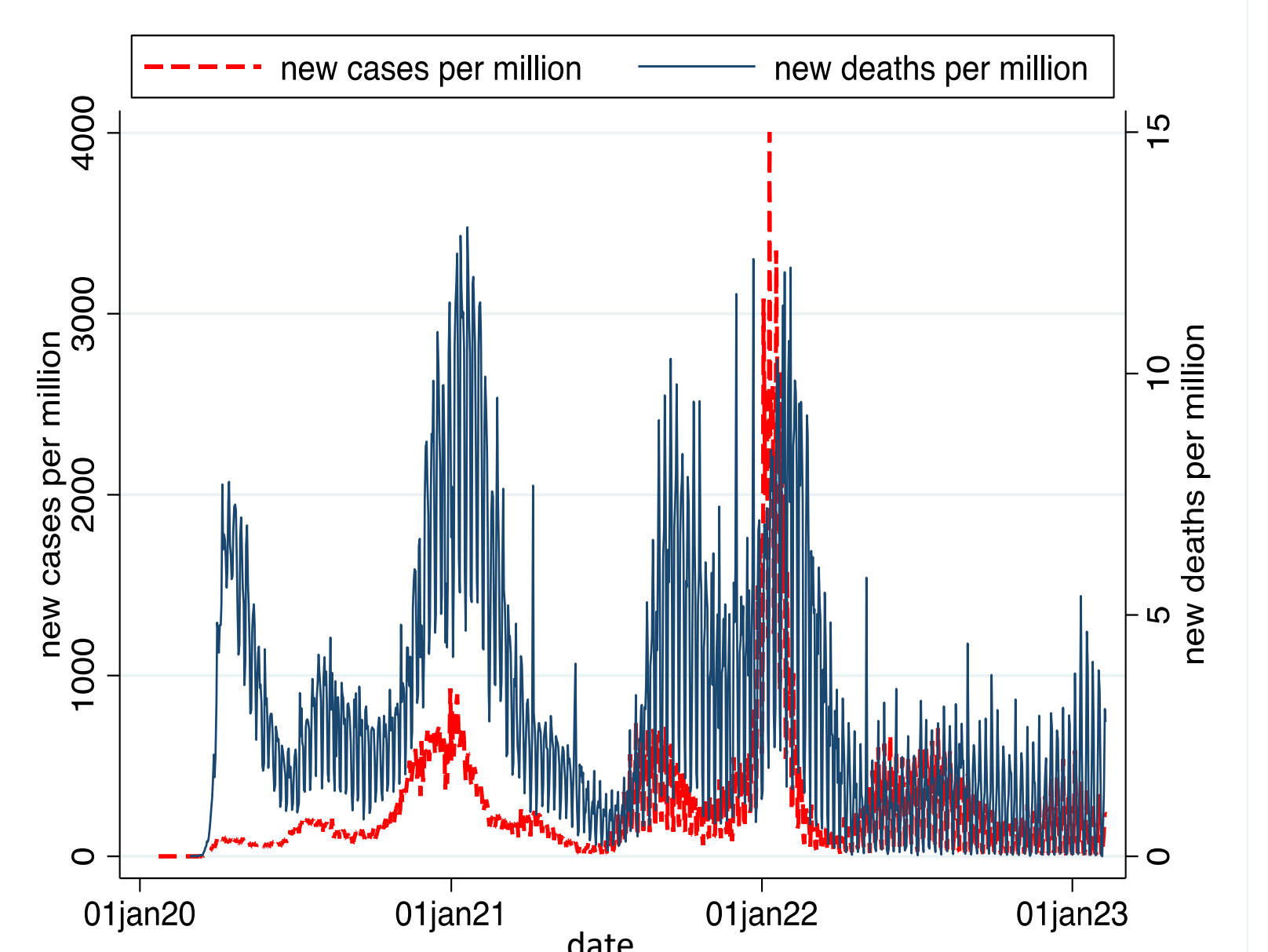


Fig 1(A). Trends of new cases per million and deaths per million from Jan 2020 till Feb 2023

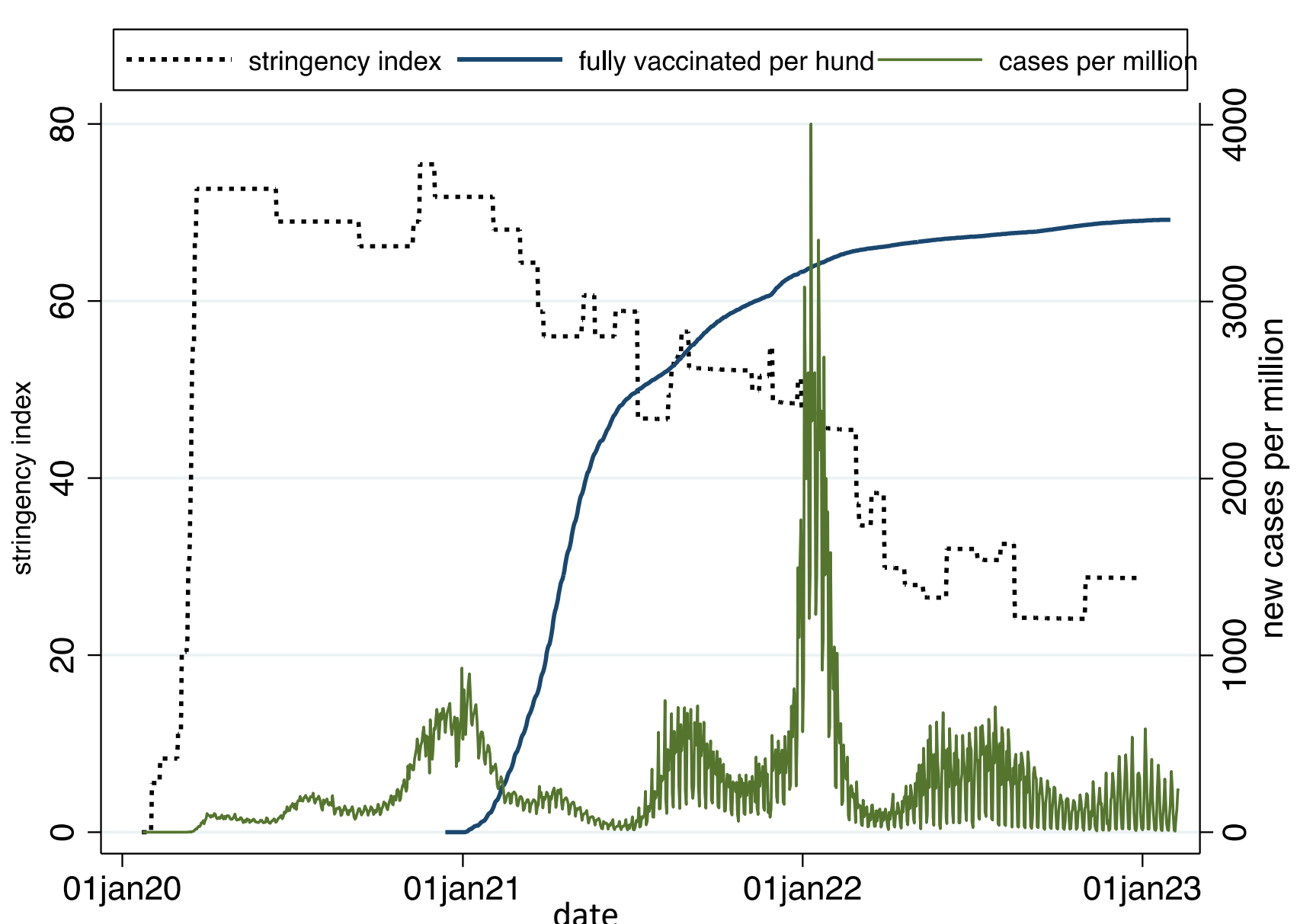


Fig 1(B). Trends of new cases per million, stringency index and people fully vaccinated from Jan 2020 till Feb 2023

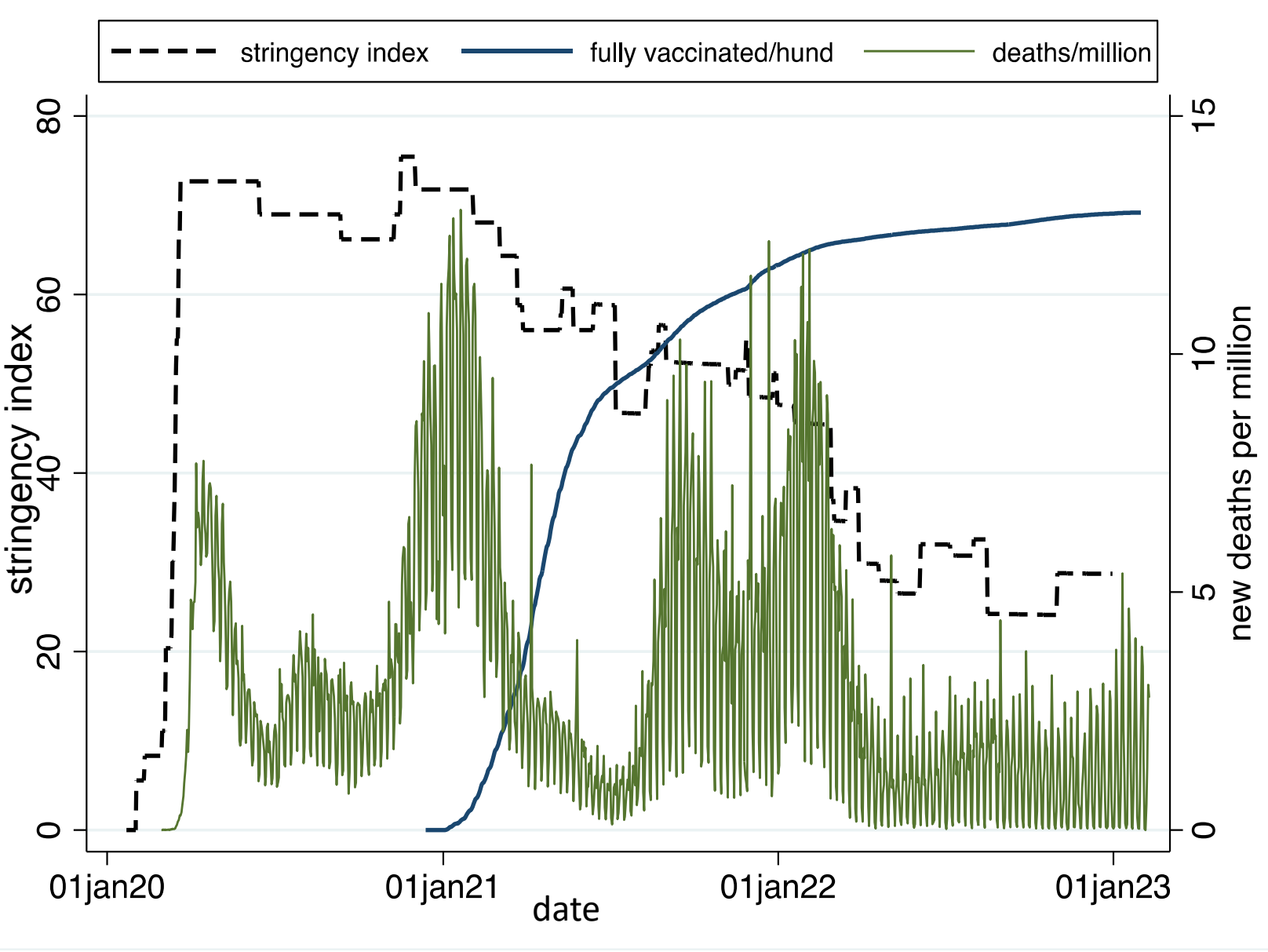


Fig 1(C). Trends of new deaths per million, stringency index, and people fully vaccinated from Jan 2020 till Feb 2023

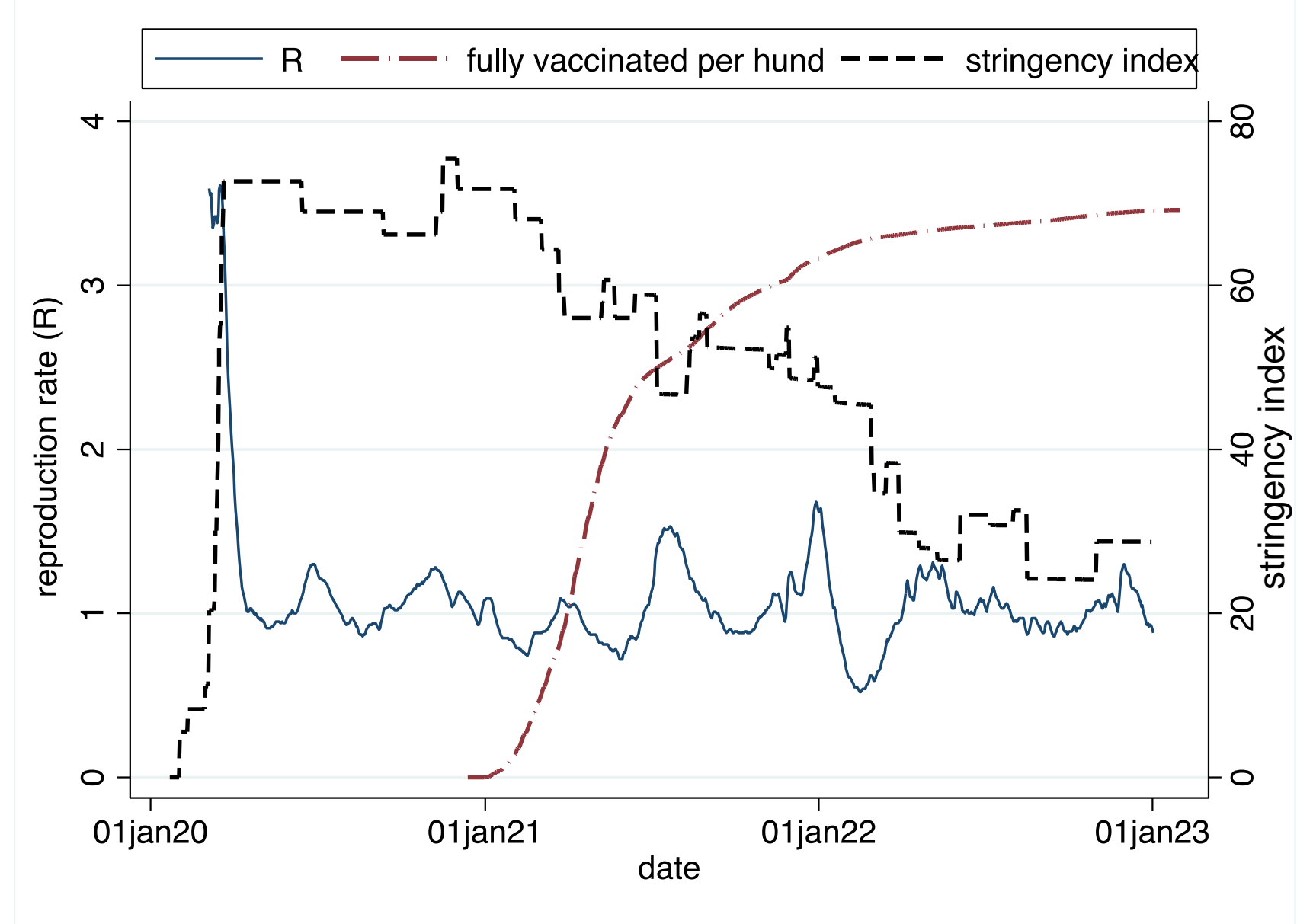


Fig 1(D). Trends of reproduction rate, stringency index, and people fully vaccinated from Jan 2020 till Feb 2023

- Despite a higher stringency index of 75, the highest number of deaths per million occurred in January 2021 (12 new deaths per million), and despite approximately 65% of the population being vaccinated, the number of new deaths per million reached its peak in January 2022.(Fig 1(C)).
- The highest reproduction rate of 3.6 occurred at the onset of the pandemic. The reproduction rate remained steady at an average of around 1, but it decreased rapidly to 0.7 when the proportion of fully vaccinated people reached approximately 70%.(Fig 1(D))

## RESULTS CONTD.

### Model Results

II. Effect of vaccinations on total COVID-19 cases				
	(1)	(2)	(3)	(4)
	Log of total cases	Log of total cases	Log of total cases	Log of total cases
Treatment effect	-2.555***	-1.977***	1.945***	0.662***
Omicron variant surge	-	1.764***	1.782***	-
Stringency*treatment	-	-	-0.052***	-0.008***
First, second, and third-order polynomial time trend	Yes	Yes	Yes	Yes
Sample	Full	Full	Full	4M
Observations	1126	1126	1075	241

III. Effect of vaccinations on total COVID-19 deaths				
	(1)	(2)	(3)	(4)
	Log of total deaths	Log of total deaths	Log of total deaths	Log of total deaths
Treatment effect	-1.291***	-1.054***	0.892***	-0.683***
Omicron variant surge	-	0.833***	0.864***	-
Stringency*treatment	-	-	-0.0260***	0.0102***
First, second, and third-order polynomial time trend	Yes	Yes	Yes	Yes
Sample	Full	Full	Full	4M
Observations	1088	1088	1037	241

IV. Effect of vaccinations on the COVID-19 reproduction rate				
	(1)	(2)	(3)	(4)
	Reproduction rate	Reproduction rate	Reproduction rate	Reproduction rate
Treatment effect	0.214***	0.144***	0.322**	0.602*
Omicron variant surge	-	-0.251***	-0.248***	-
Stringency*treatment	-	-	-0.003	-0.009**
First, second, and third-order polynomial time trend	Yes	Yes	Yes	Yes
R-square	0.290	0.306	0.306	0.764
Sample	Full	Full	Full	4M
Observations	1034	1034	1032	241

V. Effect of COVID-19 vaccinations on unemployment				
	(1)	(2)	(3)	(4)
	Total unemployment rate	Total unemployment rate	Total unemployment rate	Total unemployment rate
Treatment effect	-1.782***	-1.513***	4.509***	1.910***
Omicron variant surge	-	0.819***	0.861***	-
Stringency*treatment	-	-	-0.082***	-0.025***
First, second, and third-order polynomial time trend	Yes	Yes	Yes	Yes
R-square	0.573	0.576	0.584	0.945
Sample	Full	Full	Full	4M
Observations	1106	1106	1075	241

\* p<0.10, \*\*p<0.05, \*\*\*p<0.01; 4M indicates a partial sample based on 4 months before and after the treatments started).

- The treatment effect decreased the log of total COVID-19 cases, and the surge of the Omicron variant was positively associated with the log of total COVID-19 cases. (Table II)
- The interaction term between the treatment effects (vaccinations) and the stringency measures indicated that while the treatment effect (vaccinations) had a positive effect on the log of total COVID-19 deaths, the interaction term between the treatment effect and the stringency index was negatively associated with the total COVID-19 deaths. (Table III)
- Vaccinations were more likely to reduce the reproduction rate when some levels of societal restrictions were introduced. (Fig 4)
- RDD plot of the effect of the introduction of vaccines on the unemployment rate, the unemployment rate seemed to be declining. (Fig 5)

Fig.2 The marginal treatment effects (vaccinations) on the total COVID-19 cases

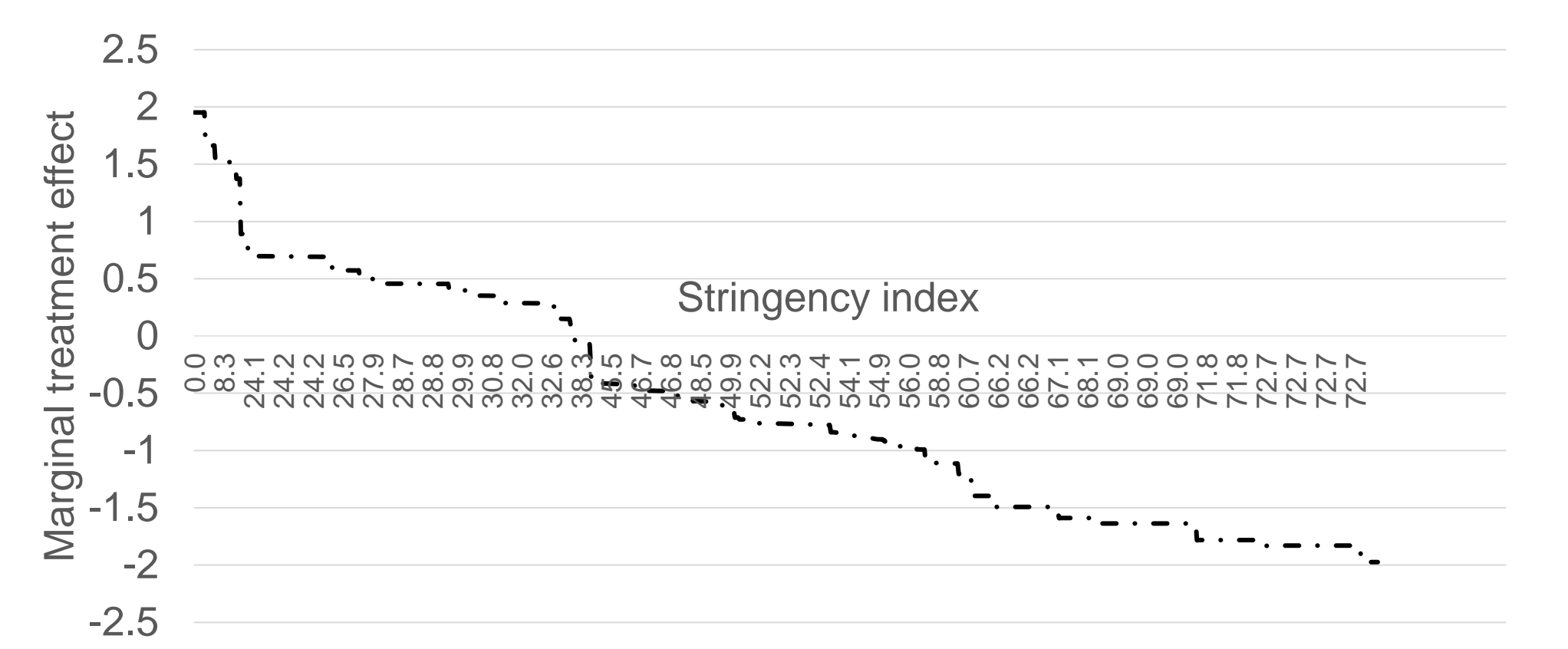


Fig.3 The marginal treatment effects (vaccinations) on the total COVID-19 deaths

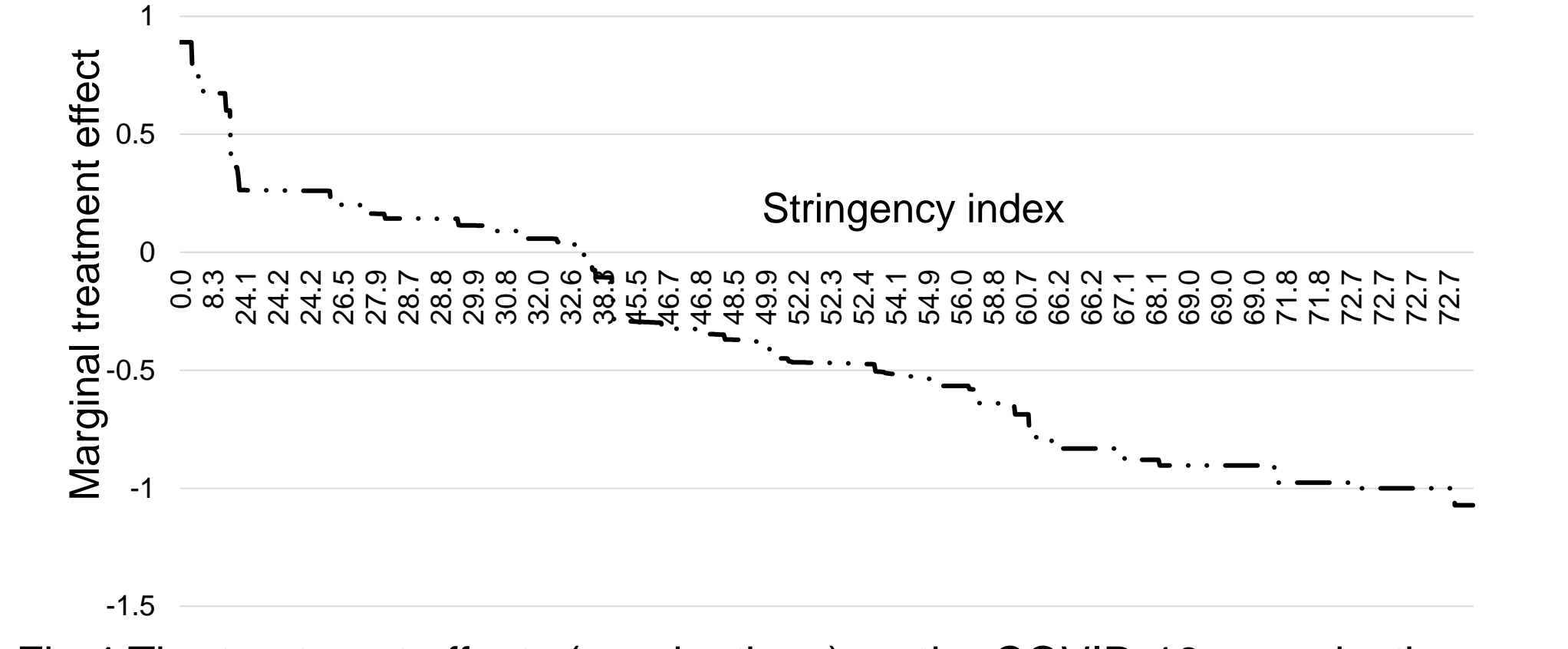


Fig.4 The treatment effects (vaccinations) on the COVID-19 reproduction rate.

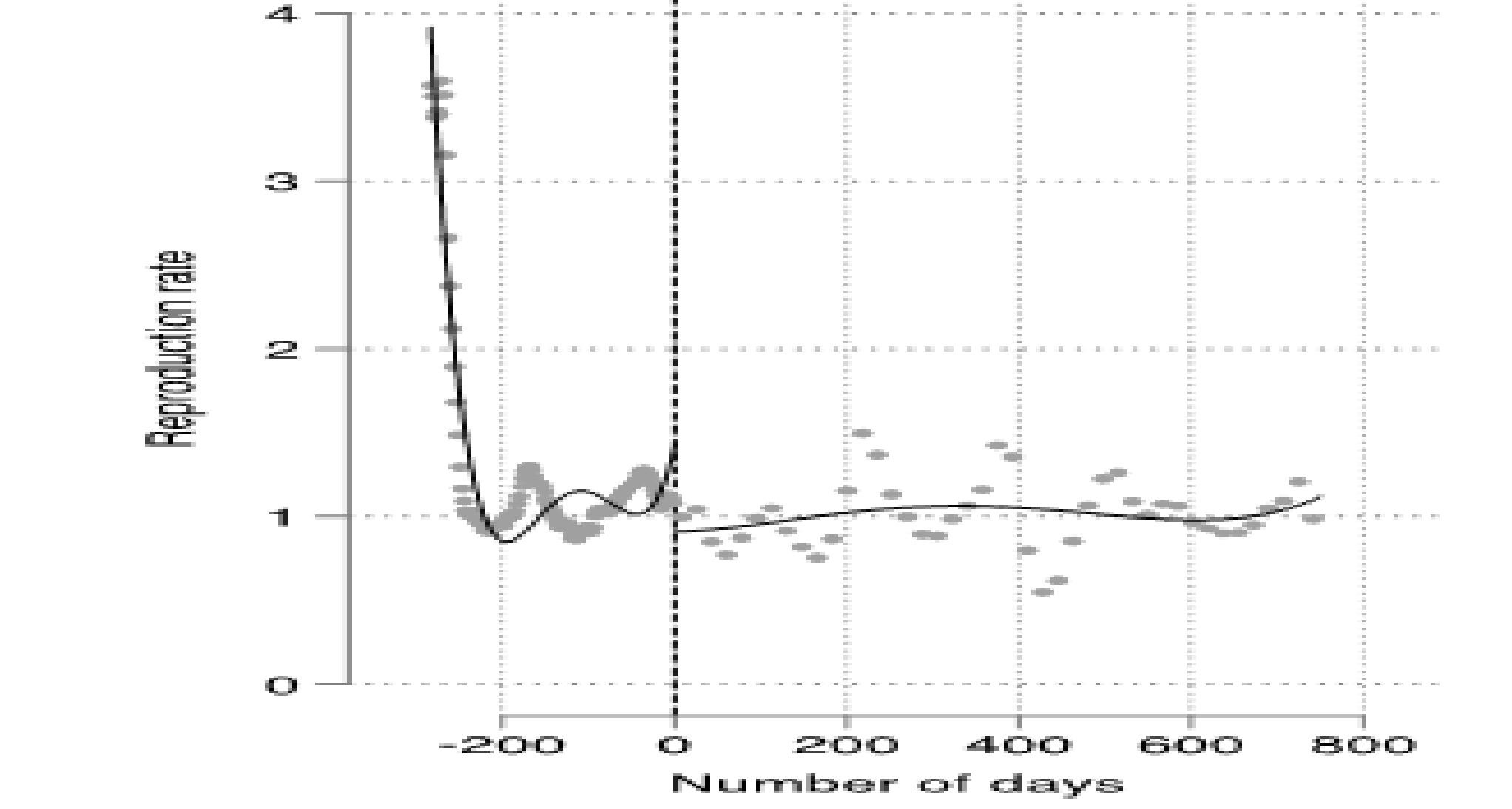
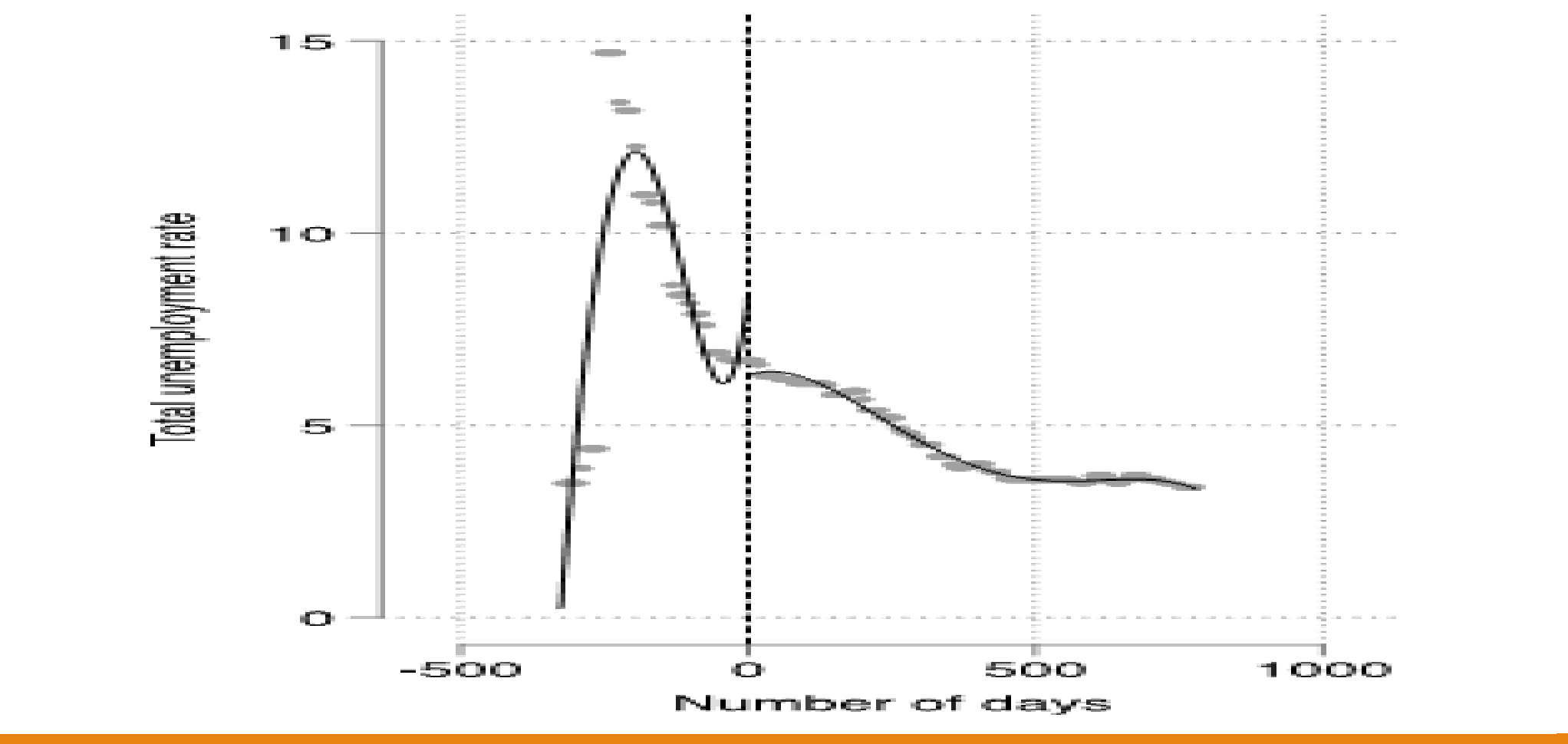


Fig.5 The treatment effects (vaccinations) on the total unemployment rate.



## CONCLUSIONS

- The interaction between treatment effects (vaccinations) and stringency measures resulted in a negative association with total COVID-19 cases and deaths.
- Vaccinations alone were not sufficient to reduce the COVID-19 spread and deaths, and that some societal restrictions might be required during the vaccination campaigns.

## LIMITATIONS

- The findings might not be generalizable to other countries.
- The effectiveness of COVID-19 vaccination and NPIs were intertwined with several confounding factors which were not accounted.