

## SUPPLEMENTARY MATERIALS

### Human mobility increased with vaccine coverage and attenuated the protection of COVID-19 vaccination: A longitudinal study of 107 countries

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### Appendix S1 Flow chart of sample selection

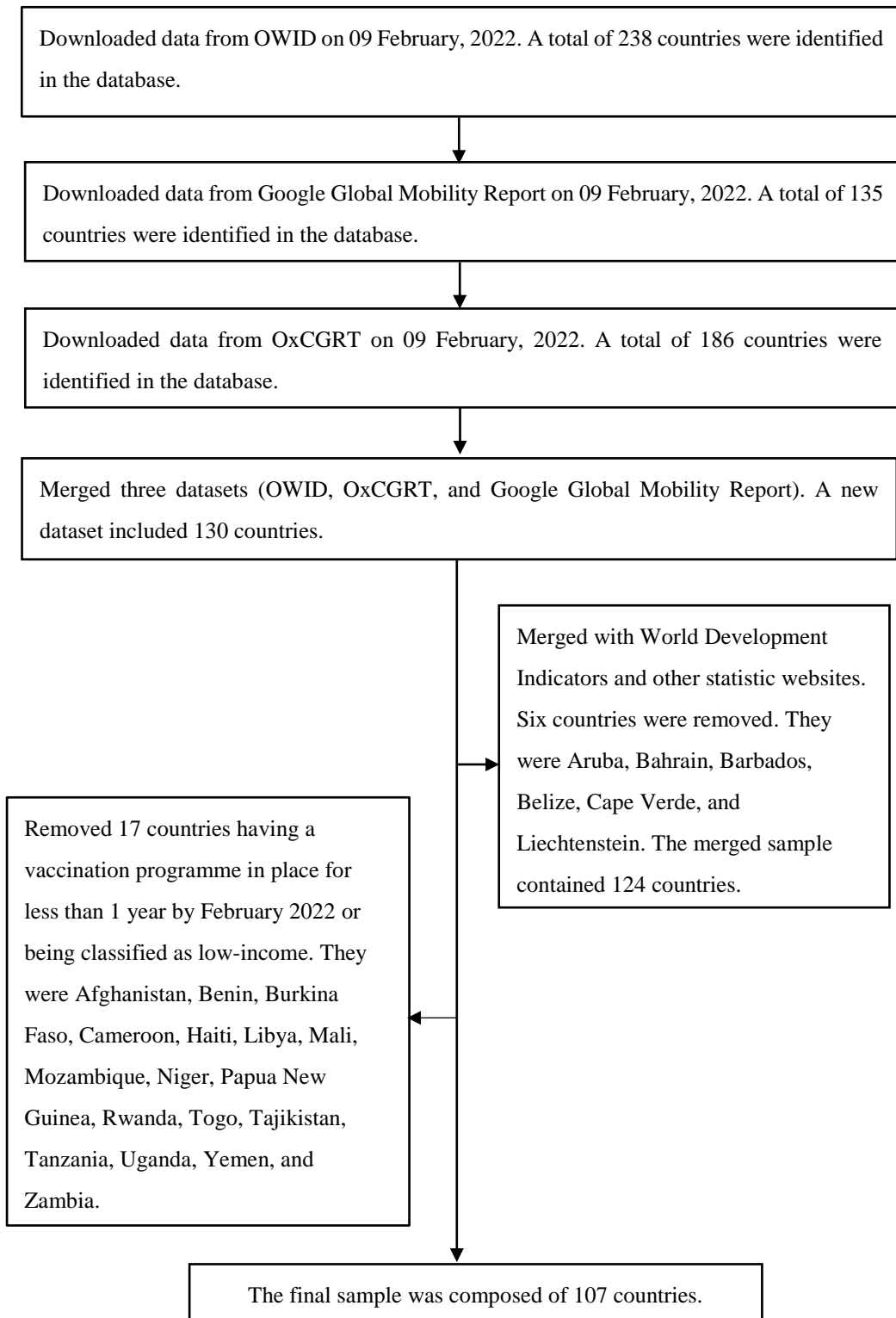


Figure S1 Flow diagram of sample selection

## Appendix S2 List of countries and control variables

### Control variables

#### *Country characteristics*

We controlled for time-invariant country characteristics that may have affected human mobility and case growth. The following country variables were used in this study: population density (hundreds of people per square kilometres of land), proportion of the population aged  $\geq 65$  years (%), per capita gross domestic product at purchasing power parity (measured in thousands of constant 2011 international dollars), the Gini index (0–100), female proportion (%), and continent indicator for each country (Europe, North America, South America, Asia, Africa, and Oceania). The data were downloaded from the World Development Indicators database published by the World Bank (<https://databank.worldbank.org/source/world-development-indicators>). Data for the prepandemic year 2019 were used.

#### *Time factors*

To control for seasonality, we included seasonal indicators in both mobility and case growth models. Because seasons differ between the northern and southern hemispheres, we manually reviewed the location of each country when constructing the variables. Moreover, to capture differences in transmissibility, the case growth model included indicators for periods when the Delta and Omicron variants were declared by the World Health Organization to be Variants of Concern (Delta: 11 May–25 November 2021, Omicron: 26 November 2021 onwards).

Table S2 provides the list of sample countries and the corresponding country characteristics.

Table S2 107 countries analysed and country characteristics

| Country                | Income level <sup>a</sup> | Hundreds of people per km <sup>2</sup> of land | Population aged 65 years or above (%) | GDP per capita (thousands of 2011 international \$) | Gini index (0-100) | Female population (%) |
|------------------------|---------------------------|--|---------------------------------------|---|--------------------|-----------------------|
| Angola                 | LMI                       | 0.2  | 2.2                                   | 5.8   | 51.3               | 51                    |
| Argentina              | UMI                       | 0.2  | 11.2                                  | 18.9  | 42.9               | 51.1                  |
| Australia              | HI                        | <0.1   | 15.9                                  | 44.6  | 34.4               | 50.2                  |
| Austria                | HI                        | 1.1  | 19.1                                  | 45.4  | 30.8               | 51                    |
| Bahamas                | HI                        | 0.4  | 7.5                                   | 27.7  | 57                 | 51                    |
| Bangladesh             | LMI                       | 12.4   | 5.2                                   | 3.5   | 32.4               | 49.6                  |
| Belarus                | UMI                       | 0.5  | 15.2                                  | 17.2  | 25.3               | 53.5                  |
| Belgium                | HI                        | 3.8  | 19                                    | 42.7  | 27.2               | 50.7                  |
| Bolivia                | LMI                       | 0.1  | 7.3                                   | 6.9   | 41.6               | 49.9                  |
| Bosnia and Herzegovina | UMI                       | 0.6  | 17.2                                  | 11.7  | 33                 | 50.9                  |
| Brazil                 | UMI                       | 0.3  | 9.3                                   | 14.1  | 53.4               | 50.9                  |
| Bulgaria               | UMI                       | 0.6  | 21.3                                  | 18.6  | 41.3               | 51.4                  |
| Botswana               | UMI                       | <0.1   | 4.4                                   | 15.8  | 53.3               | 50.6                  |

| Country            | Income level | Hundreds of people per km <sup>2</sup> of land | Population aged 65 years or above (%) | GDP per capita (thousands of 2011 international \$) | Gini index (0-100) | Female population (%) |
|--------------------|--------------|--|---------------------------------------|---|--------------------|-----------------------|
| Cambodia           | LMI          | 0.9  | 4.7                                   | 3.6   | 36.6               | 51.2                  |
| Canada             | HI           | <0.1   | 17.6                                  | 44  | 33.3               | 50.4                  |
| Chile              | HI           | 0.3  | 11.9                                  | 22.8  | 44.4               | 50.5                  |
| Colombia           | UMI          | 0.4  | 8.8                                   | 13.3  | 51.3               | 50.8                  |
| Costa Rica         | UMI          | 1.0  | 9.9                                   | 15.5  | 48.2               | 50                    |
| Cote d'Ivoire      | LMI          | 0.8  | 2.9                                   | 3.6   | 41.5               | 49.3                  |
| Croatia            | HI           | 0.7  | 20.9                                  | 22.7  | 29.7               | 51.8                  |
| Czech              | HI           | 1.4  | 19.8                                  | 32.6  | 25                 | 50.8                  |
| Denmark            | HI           | 1.4  | 20                                    | 46.7  | 28.2               | 50.3                  |
| Dominican Republic | UMI          | 2.2  | 7.3                                   | 14.6  | 41.9               | 50.2                  |
| Ecuador            | UMI          | 0.7  | 7.4                                   | 10.6  | 45.7               | 50                    |
| Egypt              | LMI          | 1.0  | 5.3                                   | 10.6  | 31.5               | 49.4                  |
| El Salvador        | LMI          | 3.1  | 8.5                                   | 7.3   | 38.8               | 53                    |
| Estonia            | HI           | 0.3  | 20                                    | 29.5  | 30.3               | 53.1                  |
| Fiji               | UMI          | 0.5  | 5.6                                   | 8.7   | 36.7               | 49.2                  |
| Finland            | HI           | 0.2  | 22.1                                  | 40.6  | 27.3               | 50.7                  |
| France             | HI           | 1.2  | 20.4                                  | 38.6  | 32.4               | 50.8                  |
| Gabon              | UMI          | 0.1  | 3.5                                   | 16.6  | 38                 | 48.6                  |
| Georgia            | UMI          | 0.7  | 15.1                                  | 9.7   | 35.9               | 52.3                  |
| Germany            | HI           | 2.4  | 21.6                                  | 45.2  | 31.9               | 50.8                  |
| Ghana              | LMI          | 1.3  | 3.1                                   | 4.2   | 43.5               | 50.2                  |
| Greece             | HI           | 0.8  | 21.9                                  | 24.6  | 32.9               | 50.8                  |
| Guatemala          | UMI          | 1.5  | 4.9                                   | 7.4   | 48.3               | 50.8                  |
| Honduras           | LMI          | 0.9  | 4.8                                   | 4.5   | 48.2               | 50.1                  |
| Hong Kong          | HI           | 71   | 17.5                                  | 56.1  | 54                 | 54                    |
| Hungary            | HI           | 1.1  | 19.7                                  | 26.8  | 29.6               | 52.4                  |
| India              | LMI          | 4.5  | 6.4                                   | 6.4   | 47.9               | 48.2                  |
| Indonesia          | LMI          | 1.5  | 6.1                                   | 11.2  | 38.2               | 49.7                  |
| Iraq               | UMI          | 0.9  | 3.4                                   | 15.7  | 29.5               | 49.4                  |
| Ireland            | HI           | 0.7  | 14.2                                  | 67.3  | 31.4               | 50.4                  |
| Israel             | HI           | 4.1  | 12.2                                  | 33.1  | 39                 | 50.3                  |
| Italy              | HI           | 2.1  | 23                                    | 35.2  | 35.9               | 51.3                  |
| Jamaica            | UMI          | 2.7  | 8.9                                   | 8.2   | 45.5               | 50.2                  |
| Japan              | HI           | 3.5  | 28                                    | 39  | 32.9               | 51.2                  |
| Jordan             | UMI          | 1.1  | 3.9                                   | 8.3   | 33.7               | 49.4                  |
| Kazakhstan         | UMI          | 0.1  | 7.7                                   | 24.1  | 27.8               | 51.6                  |

| Country      | Income level | Hundreds of people per km <sup>2</sup> of land | Population aged 65 years or above (%) | GDP per capita (thousands of 2011 international \$) | Gini index (0-100) | Female population (%) |
|--------------|--------------|--|---------------------------------------|---|--------------------|-----------------------|
| Kenya        | LMI          | 0.9  | 2.4                                   | 3   | 40.8               | 50.3                  |
| Kuwait       | HI           | 2.3  | 2.8                                   | 65.5  | 80.9               | 42.6                  |
| Kyrgyzstan   | LMI          | 0.3  | 4.6                                   | 3.4   | 29.7               | 50.4                  |
| Laos         | LMI          | 0.3  | 4.2                                   | 6.4   | 38.8               | 50.1                  |
| Latvia       | HI           | 0.3  | 20.3                                  | 25.1  | 35.1               | 54.1                  |
| Lebanon      | UMI          | 6.7  | 7.3                                   | 13.4  | 31.8               | 49.8                  |
| Lithuania    | HI           | 0.4  | 20.2                                  | 29.5  | 35.7               | 53.9                  |
| Luxembourg   | HI           | 2.5  | 14.3                                  | 94.3  | 35.4               | 49.7                  |
| Malaysia     | UMI          | 1.0  | 6.9                                   | 26.8  | 41.1               | 48.4                  |
| Malta        | HI           | 15.1   | 20.8                                  | 36.5  | 28.7               | 49.8                  |
| Mauritius    | HI           | 6.2  | 12                                    | 20.3  | 36.8               | 50.5                  |
| Mexico       | UMI          | 0.6  | 7.4                                   | 17.3  | 45.4               | 50.2                  |
| Moldova      | UMI          | 0.9  | 12                                    | 5.2   | 25.7               | 52                    |
| Mongolia     | LMI          | <0.1   | 4.2                                   | 11.8  | 32.7               | 50.5                  |
| Morocco      | LMI          | 0.8  | 7.3                                   | 7.5   | 39.5               | 50.5                  |
| Myanmar      | LMI          | 0.8  | 6                                     | 5.6   | 30.7               | 51.2                  |
| Namibia      | UMI          | <0.1   | 3.6                                   | 9.5   | 59.1               | 51.4                  |
| Nepal        | LMI          | 2.0  | 5.8                                   | 2.4   | 32.8               | 51.5                  |
| Netherlands  | HI           | 5.1  | 19.6                                  | 48.5  | 28.1               | 50.2                  |
| New Zealand  | HI           | 0.2  | 16                                    | 36.1  | 41.9               | 50.8                  |
| Nicaragua    | LMI          | 0.5  | 5.5                                   | 5.3   | 46.2               | 50.7                  |
| Nigeria      | LMI          | 2.2  | 2.7                                   | 5.3   | 35.1               | 49.3                  |
| Norway       | HI           | 0.1  | 17.3                                  | 64.8  | 27.6               | 49.5                  |
| Oman         | HI           | 0.2  | 2.4                                   | 38  | 30.7               | 34.2                  |
| Pakistan     | LMI          | 2.8  | 4.3                                   | 5   | 31.6               | 48.6                  |
| Panama       | HI           | 0.6  | 8.3                                   | 22.3  | 49.8               | 49.9                  |
| Paraguay     | UMI          | 0.2  | 6.6                                   | 8.8   | 45.7               | 49.3                  |
| Peru         | UMI          | 0.2  | 8.4                                   | 12.2  | 41.5               | 50.1                  |
| Philippines  | LMI          | 3.6  | 5.3                                   | 7.6   | 37.8               | 49.7                  |
| Poland       | HI           | 1.2  | 18.1                                  | 27.2  | 30.2               | 51.7                  |
| Portugal     | HI           | 1.1  | 22.4                                  | 27.9  | 33.5               | 52.7                  |
| Qatar        | HI           | 2.4  | 1.5                                   | 116.9   | 41.1               | 24.9                  |
| Romania      | HI           | 0.8  | 18.8                                  | 23.3  | 35.8               | 51.6                  |
| Russia       | UMI          | 0.1  | 15.1                                  | 24.8  | 37.5               | 53.5                  |
| Saudi Arabia | HI           | 0.2  | 3.4                                   | 49  | 45.9               | 42.9                  |

| Country              | Income level | Hundreds of people per km <sup>2</sup> of land | Population aged 65 years or above (%) | GDP per capita (thousands of 2011 international \$) | Gini index (0-100) | Female population (%) |
|----------------------|--------------|--|---------------------------------------|---|--------------------|-----------------------|
| Senegal              | LMI          | 0.8  | 3.1                                   | 2.5   | 40.3               | 50.9                  |
| Serbia               | UMI          | 0.8  | 18.7                                  | 14  | 30.4               | 51.1                  |
| Singapore            | HI           | 79.5   | 12.4                                  | 85.5  | 37.5               | 50.6                  |
| Slovakia             | HI           | 1.1  | 16.2                                  | 30.2  | 25                 | 51.4                  |
| Slovenia             | HI           | 1.0  | 20.2                                  | 31.4  | 24.6               | 50.3                  |
| South Africa         | UMI          | 0.5  | 5.4                                   | 12.3  | 63                 | 50.9                  |
| South Korea          | HI           | 5.3  | 15.1                                  | 35.9  | 31.4               | 50                    |
| Spain                | HI           | 0.9  | 19.6                                  | 34.3  | 34.7               | 51                    |
| Sri Lanka            | LMI          | 3.5  | 10.8                                  | 11.7  | 39.3               | 51.9                  |
| Sweden               | HI           | 0.2  | 20.2                                  | 46.9  | 30                 | 50                    |
| Switzerland          | HI           | 2.2  | 18.8                                  | 57.4  | 33.1               | 50.5                  |
| Taiwan               | HI           | 6.7  | 16                                    | 32.8  | 31.5               | 50.1                  |
| Thailand             | UMI          | 1.4  | 12.4                                  | 16.3  | 34.9               | 51.2                  |
| Trinidad and Tobago  | HI           | 2.7  | 11.1                                  | 28.8  | 40.3               | 50.7                  |
| Turkey               | UMI          | 1.1  | 8.7                                   | 25.1  | 41.9               | 50.7                  |
| Ukraine              | LMI          | 0.8  | 16.7                                  | 7.9   | 26.6               | 53.8                  |
| United Arab Emirates | HI           | 1.4  | 1.2                                   | 67.3  | 26                 | 27.6                  |
| United Kingdom       | HI           | 2.7  | 18.5                                  | 39.8  | 35.1               | 50.7                  |
| United States        | HI           | 0.4  | 16.2                                  | 54.2  | 41.4               | 50.5                  |
| Uruguay              | HI           | 0.2  | 14.9                                  | 20.6  | 39.7               | 51.7                  |
| Venezuela            | HI           | 0.3  | 7.6                                   | 16.7  | 44.8               | 50.3                  |
| Vietnam              | LMI          | 3.1  | 7.6                                   | 6.2   | 35.7               | 50.5                  |
| Zimbabwe             | LMI          | 0.4  | 3                                     | 1.9   | 50.3               | 51.3                  |

Note: HI: High income. UMI: upper-middle-income. LMI: lower-middle-income. GDP: gross domestic product.

<sup>a</sup> We used the 2022 World Bank classification, which defined income groups on the basis of 2020 per capita gross national income (GNI). HI economies referred to those with a GNI per capita of \$12,695 or more. UMI economies were those with a GNI per capita between \$4,096 and \$12,695, and LMI economies were those with a GNI per capita between \$1,046 and \$4,095.

## Appendix S3 Empirical models for human mobility and case growth

### Model I: Human mobility

Individuals may increase their mobility after vaccination against COVID-19. Therefore, we parameterised mobility as follows:

$$mobility_{i,t}^k = \beta_1^k + \beta_2^k vaccine_{i,t} + \beta_3^k stringnecy_{i,t} + \beta_4^k newcases_{i,t-1} + C_i' B_5^k + S_t' B_6^k + v_i + \varepsilon_{i,t} \quad (S3.1)$$

where  $mobility_{i,t}^k$  denotes the percentage change (relative to the baseline value) in the number of visitors to location  $k$  for country  $i$  at time  $t$ ,  $vaccine_{i,t}$  denotes the vaccine coverage,  $stringnecy_{i,t}$  denotes the stringency index, and  $newcases_{i,t-1}$  denotes the lagged number of new cases. VM was estimated by  $\beta_2^k$ , the change in mobility for one more person vaccinated against COVID-19 per 10 people in the population.  $C_i'$  and  $S_t'$  are the row vector for country characteristics and season indicators, respectively. Additionally,  $v_i$  represents unobservable time-invariant country-specific factors associated with mobility. Finally,  $\varepsilon_{i,t}$  is the usual idiosyncratic error.

Equation (S3.1) was estimated separately for the four categories of mobility ( $k = 1, \dots, 4$ ). According to the Hausman test [1], a random-effects model was preferable for some regression analyses, but a fixed-effects model was preferable for others. For consistency, we used a random-effects model as our primary model. The Breusch and Pagan Lagrange multiplier test [2] for random effects rejected our null hypothesis that the variance of  $v_i$  would be 0 ( $P < 0.001$ ) for all regression analyses, supporting the inclusion of random effects. We present the results of our fixed-effects regressions in Table S5.1, Appendix S5; we observed that both models generated similar results. Furthermore, standard errors were clustered at the country level to account for correlations of mobility data within countries over time.

### Model II: COVID-19 case growth and Gelbach decomposition

Vaccine coverage and mobility were key predictors in case growth model, which can be expressed as follows:

$$casegrowth_{i,t} = \gamma_1 + \gamma_2(vaccine_{i,t-7} - vaccine_{i,t-180}) + \gamma_3 mobility_{i,t-14} + \gamma_4 stringnecy_{i,t-14} + F_{i,t-14}' \Gamma_5 + C_i' \Gamma_6 + Z_t' \Gamma_7 + f_i + e_{i,t} \quad (S3.2)$$

where  $casegrowth_{i,t}$  denotes the growth of new cases in country  $i$  at time  $t$ , as defined in Equation (1) in the main text. Moreover,  $vaccine_{i,t-7} - vaccine_{i,t-180}$  denotes the effective coverage rate, calculated as the cumulative number of people who received at least one dose of COVID-19 vaccines per ten people from 7 days and 6 months ago.  $F_{i,t-14}'$  and  $C_i'$  represent row vectors for face-covering policies and country characteristics, respectively.  $Z_t'$  represents indicators for seasons and Delta and Omicron periods. Mobility, the stringency index, and face-covering policies were all lagged by 14 days to account for incubation after contact and possible delays in case detection. Finally,  $f_i$  denotes time-invariant unobservable country effects.  $e_{i,t}$  denotes the idiosyncratic error.

Our objective was to evaluate changes in case growth within countries over time; furthermore, the Hausman test indicated that a fixed-effects model would be preferable to a random-effects model. Consequently, we treated  $f_i$  as fixed and thus could not estimate time-invariant country characteristics from Equation (S3.2). In addition, because the four

mobility variables (retail and recreation, grocery stores and pharmacies, transit stations, and workplaces) were highly correlated (correlation coefficient: 0.6–0.9,  $P < 0.001$ ), we included them in the model individually. Standard errors were clustered at the country level to correct for serial correlations.

We examined whether VM would reduce the effectiveness of vaccines against COVID-19 infection. In estimating the indirect effect of mobility through vaccination, we adopted the decomposition method proposed by Gelbach [3]. Specifically, we compared the value of the vaccine coverage coefficient in Equation (S3.2) derived when mobility was excluded from the model (base model) with that derived when mobility was included in the model (full model).

### **References:**

1. Hausman JA, Taylor WE. Panel data and unobservable individual effects. *Econometrica* 1981;49:1377-98.
2. Breusch TS, Pagan AR. The Lagrange multiplier test and its applications to model specification in econometrics. *The Review of Economic Studies*. 1980;47:239-53.
3. Gelbach JB. When do covariates matter? And which ones, and how much. *Journal of Labour Economics*. 2016;34:509–43.



## Appendix S4 Gelbach decomposition method

By using least-squares identity, Gelbach (2016) [1] demonstrated that the difference in coefficient between the base and full models was equivalent to the omitted variables bias. Consider a population regression model (Gelbach, p.518)

$$Y = X_1\beta_1 + X_2\beta_2 + \varepsilon \quad (\text{S4.1})$$

and define  $\beta = [\beta_1', \beta_2']'$ ,  $X = [X_1, X_2]$ . We call this *full model*. The ordinary least squares (OLS) estimator is given by  $\hat{\beta} = (X'X)^{-1}X'Y$ . Denote the first and second component of  $\hat{\beta}$  as  $\hat{\beta}_1^{full}$  and  $\hat{\beta}_2$ , respectively. Under usual conditions,  $\hat{\beta}_1^{full}$  is a consistent estimator for  $\beta_1$ . Now suppose  $X_2$  is omitted from the full model, and the base model is written as

$$Y = X_1\beta_1^{base} + \epsilon, \quad (\text{S4.2})$$

where the OLS estimator is  $\hat{\beta}_1^{base} = (X_1'X_1)^{-1}X_1'Y$ . Its probability limit is

$$plim\hat{\beta}_1^{base} = \beta_1 + plim(X_1'X_1)^{-1}X_1'X_2\beta_2, \quad (\text{S4.3})$$

$$\text{or } \beta_1^{base} = \beta_1 + \Gamma\beta_2 = \beta_1 + \delta, \quad (\text{S4.4})$$

where  $\Gamma$  is the matrix of coefficients from regressing  $X_2$  on  $X_1$ , and  $\delta$  represents the difference in the population coefficients between the base and full models, or the population omitted variables bias resulted from excluding  $X_2$  when estimating  $\beta_1$ . Note that  $\delta$  is non-zero when  $E[X_1X_2] \neq 0$ .

Gelbach (p. 521) further pointed out that since  $plim\hat{\beta}_1^{base} = \beta_1 + \delta$ , and because  $\beta_1$  is consistent for  $\hat{\beta}_1^{full}$ ,  $\delta$  can be estimated as  $\hat{\delta} \equiv \hat{\beta}_1^{base} - \hat{\beta}_1^{full}$ , which is just empirically comparing the base and full models. To prove that  $\hat{\delta}$  identically equals the sample omitted variables bias formula,  $(X_1'X_1)^{-1}X_1'X_2\hat{\beta}_2$ , let's express (S4.1) in the sample analogue:

$$\hat{Y} = X_1\hat{\beta}_1^{full} + X_2\hat{\beta}_2 + \hat{\varepsilon}, \quad (\text{S4.5})$$

where  $\hat{\varepsilon}$  is the residuals. Pre-multiplying both sides by  $(X_1'X_1)^{-1}X_1'$  generates  $\hat{\beta}_1^{base} = \hat{\beta}_1^{full} + (X_1'X_1)^{-1}X_1'X_2\hat{\beta}_2$ . Therefore,  $\hat{\delta} \equiv \hat{\beta}_1^{base} - \hat{\beta}_1^{full} = (X_1'X_1)^{-1}X_1'X_2\hat{\beta}_2$ .

In our case growth model, because fixed-effects were assumed, we first demeaned (centred) all covariates, and then estimated the model by usual OLS linear regressions before applying Gelbach formula.

### Reference:

1. Gelbach JB. When do covariates matter? And which ones, and how much. *Journal of Labour Economics*. 2016;34:509–43.

## Appendix S5 Robustness checks for mobility model

For robustness checks of mobility model, we used five alternative specifications. First, we applied the fixed-effects instead of random-effects regressions (Table S5.1). Second, we replaced the mobility outcome with its 7-day moving average (Table S5.2). Third, the key predictor, vaccine coverage was lagged by 7 days to allow for a delay in behaviour response (Table S5.3). Fourth, we used an instrumental variable approach to re-estimate the mobility model to tackle the potential existence of unobserved time-variant confounders. In this model, vaccine coverage was instrumented using the 2019 government effectiveness score obtained from Worldwide Governance Indicators [1,2] and an ordinal variable for COVID-19 vaccine availability obtained from the Oxford COVID-19 Government Response Tracker (OxCGRT) [3]. The government effectiveness score ranged from -2.5 to 2.5, with a higher value indicating better governance. The vaccine availability had three values: 0 refers to “no categories are receiving vaccines”, 1 refers to “vaccines are available to some categories”, and 2 refers to “vaccines are available to anyone over the age of 16 years”. We selected these instrumental variables because they were highly correlated with the level of vaccine coverage but were unlikely to be correlated with mobility. The instrumental variable estimation resulted in a slightly increased magnitude of the positive coefficient of mobility, but the main conclusions remained robust (Table S5.4).

Finally, we investigated whether booster doses increased mobility and changed the association between mobility and vaccine coverage. A variable called “total boosters” was retrieved from Our World in Data [4]. The variable recorded the total number of COVID-19 booster doses administered each day per country. Boosters are only available for fully vaccinated people, namely, those who received all doses prescribed by the initial vaccination protocol. Therefore, we divided the cumulative number of boosters by the cumulative number of fully vaccinated people. The ratio was multiplied by 10 for the convenience of interpretation. The variable was then included in the mobility model and interacted with the vaccine coverage. The results are presented in Table S5.5. The average marginal effects showed that the number of boosters was not associated with human mobility in any location category. For example, the third to last row in the table showed that, the number of visitors to retail and recreation increased by 0.27 percentage point when the number of boosters (per ten fully vaccinated people) increased by one; however, the association was not statistically significant (95% confidence interval -3.16 to 3.69;  $P=0.879$ ). Overall, the inclusion of booster variables did not change the key finding that COVID-19 vaccine coverage was associated with increased human mobility.

### References:

1. Kaufmann D, Kraay A, Mastruzzi M. The Worldwide Governance Indicators: methodology and analytical Issues. Washington DC: The World Bank, 2010.
2. The World Bank. Worldwide Governance Indicators. Available from: <http://info.worldbank.org/governance/wgi/#home> [accessed 15 Jan. 2023].
3. Hale T, Angrist N, Goldszmidt R, Kira B, Petherick A, Phillips T, et al. A global panel database of pandemic policies (Oxford COVID-19 Government Response Tracker). *Nature Human Behaviour*. 2021;5:529-38.
4. Data on COVID-19 (coronavirus) vaccinations by Our World in Data. 2020. Available from: <https://github.com/owid/covid-19-data/tree/master/public/data/vaccinations> [accessed 15 Jan. 2023].

Table S5.1 Results from mobility model, assuming country fixed effects

| Y: daily mobility change (%)                  | <b>Retail and recreation</b> |      |        | <b>Grocery and pharmacy</b> |      |        | <b>Transit stations</b> |      |        | <b>Workplaces</b> |      |        |
|---|------------------------------|------|--------|-----------------------------|------|--------|-------------------------|------|--------|-------------------|------|--------|
|   | Coef.                        | SE   | P>z    | Coef.                       | SE   | P>z    | Coef.                   | SE   | P>z    | Coef.             | SE   | P>z    |
| <b>Panel A: all countries</b>                 |                              |      |        |                             |      |        |                         |      |        |                   |      |        |
| No. of people vaccinated (per ten people)     | 3.59                         | 0.25 | <0.001 | 4.28                        | 0.32 | <0.001 | 2.72                    | 0.28 | <0.001 | 1.38              | 0.16 | <0.001 |
| Stringency index                              | -0.78                        | 0.03 | <0.001 | -0.57                       | 0.04 | <0.001 | -0.76                   | 0.03 | <0.001 | -0.46             | 0.02 | <0.001 |
| No. of new cases (per 10,000 people, 1 lag)   | -0.46                        | 0.09 | <0.001 | -0.25                       | 0.09 | <0.001 | -0.45                   | 0.09 | <0.001 | -0.17             | 0.05 | 0.001  |
| <i>N (No. of countries)</i>                   | 75,643 (107)                 |      |        | 75,633 (107)                |      |        | 75,578 (107)            |      |        | 75,587 (107)      |      |        |
| <b>Panel B: high income countries</b>         |                              |      |        |                             |      |        |                         |      |        |                   |      |        |
| No. of people vaccinated (per ten people)     | 2.73                         | 0.25 | <0.001 | 3.24                        | 0.28 | <0.001 | 2.04                    | 0.31 | <0.001 | 0.96              | 0.17 | <0.001 |
| Stringency index                              | -0.72                        | 0.03 | <0.001 | -0.34                       | 0.03 | <0.001 | -0.63                   | 0.03 | <0.001 | -0.43             | 0.02 | <0.001 |
| No. of new cases (per 10,000 people, 1 lag)   | -0.31                        | 0.08 | <0.001 | -0.21                       | 0.06 | 0.001  | -0.36                   | 0.07 | <0.001 | -0.10             | 0.04 | 0.017  |
| <i>N (No. of countries)</i>                   | 35,582 (50)                  |      |        | 35,576 (50)                 |      |        | 35,557 (50)             |      |        | 35,579 (50)       |      |        |
| <b>Panel C: upper-middle income countries</b> |                              |      |        |                             |      |        |                         |      |        |                   |      |        |
| No. of people vaccinated (per ten people)     | 4.93                         | 0.58 | <0.001 | 5.98                        | 0.58 | <0.001 | 4.05                    | 0.57 | <0.001 | 2.08              | 0.35 | <0.001 |
| Stringency index                              | -0.69                        | 0.05 | <0.001 | -0.56                       | 0.05 | <0.001 | -0.74                   | 0.05 | <0.001 | -0.45             | 0.03 | <0.001 |
| No. of new cases (per 10,000 people, 1 lag)   | -0.65                        | 0.20 | 0.003  | 0.15                        | 0.20 | 0.465  | -0.61                   | 0.17 | 0.001  | -0.39             | 0.16 | 0.019  |
| <i>N (No. of countries)</i>                   | 21,074 (30)                  |      |        | 21,076 (30)                 |      |        | 21,040 (30)             |      |        | 21,112 (30)       |      |        |
| <b>Panel D: lower-middle income countries</b> |                              |      |        |                             |      |        |                         |      |        |                   |      |        |
| No. of people vaccinated (per ten people)     | 6.00                         | 0.81 | <0.001 | 7.90                        | 1.32 | <0.001 | 4.50                    | 0.90 | <0.001 | 2.54              | 0.61 | <0.001 |
| Stringency index                              | -0.89                        | 0.06 | <0.001 | -0.90                       | 0.07 | <0.001 | -0.93                   | 0.08 | <0.001 | -0.50             | 0.06 | <0.001 |
| No. of new cases (per 10,000 people, 1 lag)   | -0.21                        | 0.43 | 0.636  | 1.24                        | 0.54 | 0.031  | 0.52                    | 0.54 | 0.350  | 0.26              | 0.36 | 0.473  |
| <i>N (No. of countries)</i>                   | 18,987 (27)                  |      |        | 18,981 (27)                 |      |        | 18,981 (27)             |      |        | 18,896 (27)       |      |        |

Note: Fixed-effects models were applied. Other covariates not shown in the table were: population density, the share of people aged 65 or over, GDP per capita, Gini index, % female population, and indicators for continent and season. Countries were categorized into three income groups based on the 2020 per capita gross national income. Standard errors were clustered at the country level.

Table S5.2 Results from mobility model, using the 7-day moving average for mobility outcome

| Y: mobility change, 7-day moving average (%)  | Retail and recreation |      |        | Grocery and pharmacy |      |        | Transit stations |      |        | Workplaces   |      |        |
|---|-----------------------|------|--------|----------------------|------|--------|------------------|------|--------|--------------|------|--------|
|   | Coef.                 | SE   | P>z    | Coef.                | SE   | P>z    | Coef.            | SE   | P>z    | Coef.        | SE   | P>z    |
| <b>Panel A: all countries</b>                 |                       |      |        |                      |      |        |                  |      |        |              |      |        |
| No. of people vaccinated (per ten people)     | 3.53                  | 0.25 | <0.001 | 4.28                 | 0.32 | <0.001 | 2.68             | 0.28 | <0.001 | 1.32         | 0.16 | <0.001 |
| Stringency index                              | -0.78                 | 0.03 | <0.001 | -0.56                | 0.04 | <0.001 | -0.76            | 0.03 | <0.001 | -0.46        | 0.02 | <0.001 |
| No. of new cases (per 10,000 people, 1 lag)   | -0.44                 | 0.09 | <0.001 | -0.23                | 0.09 | 0.008  | -0.44            | 0.08 | <0.001 | -0.17        | 0.05 | 0.001  |
| <i>N (No. of countries)</i>                   | 75,687 (107)          |      |        | 75,670 (107)         |      |        | 75,611 (107)     |      |        | 75,602 (107) |      |        |
| <b>Panel B: high income countries</b>         |                       |      |        |                      |      |        |                  |      |        |              |      |        |
| No. of people vaccinated (per ten people)     | 2.68                  | 0.24 | <0.001 | 3.24                 | 0.28 | <0.001 | 1.99             | 0.31 | <0.001 | 0.92         | 0.17 | <0.001 |
| Stringency index                              | -0.72                 | 0.03 | <0.001 | -0.33                | 0.03 | <0.001 | -0.64            | 0.04 | <0.001 | -0.43        | 0.02 | <0.001 |
| No. of new cases (per 10,000 people, 1 lag)   | -0.29                 | 0.07 | <0.001 | -0.20                | 0.05 | <0.001 | -0.34            | 0.07 | <0.001 | -0.11        | 0.05 | 0.016  |
| <i>N (No. of countries)</i>                   | 35,582 (50)           |      |        | 35,582 (50)          |      |        | 35,563 (50)      |      |        | 35,582 (50)  |      |        |
| <b>Panel C: upper-middle income countries</b> |                       |      |        |                      |      |        |                  |      |        |              |      |        |
| No. of people vaccinated (per ten people)     | 4.84                  | 0.58 | <0.001 | 5.98                 | 0.57 | <0.001 | 3.98             | 0.57 | <0.001 | 1.99         | 0.35 | <0.001 |
| Stringency index                              | -0.70                 | 0.04 | <0.001 | -0.55                | 0.05 | <0.001 | -0.75            | 0.05 | <0.001 | -0.45        | 0.03 | <0.001 |
| No. of new cases (per 10,000 people, 1 lag)   | -0.62                 | 0.20 | 0.002  | 0.09                 | 0.18 | 0.606  | -0.59            | 0.17 | 0.001  | -0.40        | 0.16 | 0.010  |
| <i>N (No. of countries)</i>                   | 21,099 (30)           |      |        | 21,101 (30)          |      |        | 21,061 (30)      |      |        | 21,118 (30)  |      |        |
| <b>Panel D: lower-middle income countries</b> |                       |      |        |                      |      |        |                  |      |        |              |      |        |
| No. of people vaccinated (per ten people)     | 5.91                  | 0.82 | <0.001 | 7.87                 | 1.33 | <0.001 | 4.44             | 0.91 | <0.001 | 2.43         | 0.61 | <0.001 |
| Stringency index                              | -0.88                 | 0.06 | <0.001 | -0.89                | 0.07 | <0.001 | -0.92            | 0.08 | <0.001 | -0.50        | 0.06 | <0.001 |
| No. of new cases (per 10,000 people, 1 lag)   | -0.15                 | 0.41 | 0.705  | 1.32                 | 0.52 | 0.012  | 0.62             | 0.52 | 0.227  | 0.30         | 0.39 | 0.443  |
| <i>N (No. of countries)</i>                   | 19,006 (27)           |      |        | 18,987 (27)          |      |        | 18,987 (27)      |      |        | 18,902 (27)  |      |        |

Note: Random-effects models were applied. The included common covariates not shown in the table were population density, the share of people aged 65 or over, GDP per capita, Gini index, % female population, and indicators for continent and season. Countries were categorized into three income groups based on the 2020 per capita gross national income. Standard errors were clustered at the country level.

Table S5.3 Results from mobility model: using the lagged vaccine coverage as key predictor

| Y: daily mobility change (%)                      | Retail and recreation |      |        | Grocery and pharmacy |      |        | Transit stations |      |        | Workplaces   |      |        |
|---|-----------------------|------|--------|----------------------|------|--------|------------------|------|--------|--------------|------|--------|
|   | Coef.                 | SE   | P>z    | Coef.                | SE   | P>z    | Coef.            | SE   | P>z    | Coef.        | SE   | P>z    |
| <b>Panel A: all countries</b>                     |                       |      |        |                      |      |        |                  |      |        |              |      |        |
| No. of people vaccinated (per ten people, 7 lags) | 3.55                  | 0.26 | <0.001 | 4.17                 | 0.33 | <0.001 | 2.68             | 0.28 | <0.001 | 1.38         | 0.17 | <0.001 |
| Stringency index                                  | -0.80                 | 0.03 | <0.001 | -0.61                | 0.04 | <0.001 | -0.78            | 0.04 | <0.001 | -0.46        | 0.02 | <0.001 |
| No. of new cases (per 10,000 people, 1 lag)       | -0.47                 | 0.09 | <0.001 | -0.25                | 0.09 | 0.006  | -0.45            | 0.09 | <0.001 | -0.16        | 0.05 | 0.001  |
| <i>N</i> (No. of countries)                       | 75,006 (107)          |      |        | 74,996 (107)         |      |        | 74,941 (107)     |      |        | 74,950 (107) |      |        |
| <b>Panel B: high income countries</b>             |                       |      |        |                      |      |        |                  |      |        |              |      |        |
| No. of people vaccinated (per ten people, 7 lags) | 2.72                  | 0.25 | <0.001 | 3.21                 | 0.28 | <0.001 | 2.04             | 0.32 | <0.001 | 0.96         | 0.17 | <0.001 |
| Stringency index                                  | -0.73                 | 0.04 | <0.001 | -0.35                | 0.04 | <0.001 | -0.63            | 0.04 | <0.001 | -0.42        | 0.03 | <0.001 |
| No. of new cases (per 10,000 people, 1 lag)       | -0.32                 | 0.08 | <0.001 | -0.21                | 0.06 | <0.001 | -0.36            | 0.07 | <0.001 | -0.10        | 0.04 | 0.016  |
| <i>N</i> (No. of countries)                       | 35,282 (50)           |      |        | 35,276 (50)          |      |        | 35,257 (50)      |      |        | 35,279 (50)  |      |        |
| <b>Panel C: upper-middle income countries</b>     |                       |      |        |                      |      |        |                  |      |        |              |      |        |
| No. of people vaccinated (per ten people, 7 lags) | 4.91                  | 0.58 | <0.001 | 5.86                 | 0.58 | <0.001 | 4.04             | 0.55 | <0.001 | 2.13         | 0.35 | <0.001 |
| Stringency index                                  | -0.72                 | 0.05 | <0.001 | -0.60                | 0.05 | <0.001 | -0.76            | 0.06 | <0.001 | -0.44        | 0.03 | <0.001 |
| No. of new cases (per 10,000 people, 1 lag)       | -0.65                 | 0.20 | 0.001  | 0.14                 | 0.19 | 0.473  | -0.61            | 0.17 | <0.001 | -0.38        | 0.16 | 0.015  |
| <i>N</i> (No. of countries)                       | 20,895 (30)           |      |        | 20,897 (30)          |      |        | 20,861 (30)      |      |        | 20,933 (30)  |      |        |
| <b>Panel D: lower-middle income countries</b>     |                       |      |        |                      |      |        |                  |      |        |              |      |        |
| No. of people vaccinated (per ten people, 7 lags) | 6.03                  | 0.81 | <0.001 | 7.86                 | 1.31 | <0.001 | 4.49             | 0.90 | <0.001 | 2.61         | 0.63 | <0.001 |
| Stringency index                                  | -0.91                 | 0.06 | <0.001 | -0.95                | 0.07 | <0.001 | -0.96            | 0.08 | <0.001 | -0.51        | 0.07 | <0.001 |
| No. of new cases (per 10,000 people, 1 lag)       | -0.24                 | 0.41 | 0.554  | 1.19                 | 0.52 | 0.022  | 0.48             | 0.52 | 0.353  | 0.24         | 0.35 | 0.483  |
| <i>N</i> (No. of countries)                       | 18,829 (27)           |      |        | 18,823 (27)          |      |        | 18,823 (27)      |      |        | 18,738 (27)  |      |        |

Note: Random-effects models were applied. The included common covariates not shown in the table were population density, the share of people aged 65 or over, GDP per capita, Gini index, % female population, and indicators for continent and season. Countries were categorized into three income groups based on the 2020 per capita gross national income. Standard errors were clustered at the country level.

Table S5.4 Results from mobility model: using instrumental variables for vaccine coverage

| Y: daily mobility change (%)                  | Retail and recreation |      |                     | Grocery and pharmacy |      |                     | Transit stations |      |                     | Workplaces   |      |                     |
|---|-----------------------|------|---------------------|----------------------|------|---------------------|------------------|------|---------------------|--------------|------|---------------------|
|   | Coef.                 | SE   | <i>P</i> > <i>z</i> | Coef.                | SE   | <i>P</i> > <i>z</i> | Coef.            | SE   | <i>P</i> > <i>z</i> | Coef.        | SE   | <i>P</i> > <i>z</i> |
| <b>Panel A: all countries</b>                 |                       |      |                     |                      |      |                     |                  |      |                     |              |      |                     |
| No. of people vaccinated (per ten people)     | 4.35                  | 0.37 | <.001               | 5.55                 | 0.51 | <.001               | 3.56             | 0.40 | <.001               | 1.46         | 0.21 | <.001               |
| Stringency index                              | -0.75                 | 0.03 | <.001               | -0.53                | 0.04 | <.001               | -0.74            | 0.03 | <.001               | -0.46        | 0.02 | <.001               |
| No. of new cases (per 10,000 people, 1 lag)   | -0.57                 | 0.12 | <.001               | -0.38                | 0.13 | 0.002               | -0.56            | 0.11 | <.001               | -0.17        | 0.06 | 0.003               |
| <i>N</i> (No. of countries)                   | 74,836 (107)          |      |                     | 74,826 (107)         |      |                     | 74,771 (107)     |      |                     | 74,793 (107) |      |                     |
| <b>Panel B: high income countries</b>         |                       |      |                     |                      |      |                     |                  |      |                     |              |      |                     |
| No. of people vaccinated (per ten people)     | 2.92                  | 0.27 | <.001               | 3.67                 | 0.33 | <.001               | 2.40             | 0.38 | <.001               | 1.02         | 0.19 | <.001               |
| Stringency index                              | -0.72                 | 0.03 | <.001               | -0.32                | 0.03 | <.001               | -0.62            | 0.03 | <.001               | -0.43        | 0.02 | <.001               |
| No. of new cases (per 10,000 people, 1 lag)   | -0.34                 | 0.09 | <.001               | -0.25                | 0.07 | <.001               | -0.40            | 0.08 | <.001               | -0.11        | 0.04 | 0.011               |
| <i>N</i> (No. of countries)                   | 35,262 (50)           |      |                     | 35,256 (50)          |      |                     | 35,237 (50)      |      |                     | 35,259 (50)  |      |                     |
| <b>Panel C: upper-middle income countries</b> |                       |      |                     |                      |      |                     |                  |      |                     |              |      |                     |
| No. of people vaccinated (per ten people)     | 6.19                  | 1.06 | <.001               | 8.00                 | 1.53 | <.001               | 5.41             | 1.07 | <.001               | 2.30         | 0.50 | <.001               |
| Stringency index                              | -0.65                 | 0.05 | <.001               | -0.48                | 0.07 | <.001               | -0.69            | 0.07 | <.001               | -0.44        | 0.03 | <.001               |
| No. of new cases (per 10,000 people, 1 lag)   | -0.94                 | 0.28 | 0.001               | -0.13                | 0.36 | 0.721               | -0.91            | 0.25 | <.001               | -0.50        | 0.18 | 0.005               |
| <i>N</i> (No. of countries)                   | 20,880 (30)           |      |                     | 20,882 (30)          |      |                     | 20,846 (30)      |      |                     | 20,918 (30)  |      |                     |
| <b>Panel D: lower-middle income countries</b> |                       |      |                     |                      |      |                     |                  |      |                     |              |      |                     |
| No. of people vaccinated (per ten people)     | 8.38                  | 1.38 | <.001               | 10.78                | 1.96 | <.001               | 6.26             | 1.26 | <.001               | 2.72         | 0.87 | 0.002               |
| Stringency index                              | -0.86                 | 0.06 | <.001               | -0.86                | 0.07 | <.001               | -0.91            | 0.08 | <.001               | -0.50        | 0.06 | <.001               |
| No. of new cases (per 10,000 people, 1 lag)   | -0.98                 | 0.69 | 0.153               | 0.31                 | 0.89 | 0.724               | -0.05            | 0.77 | 0.948               | 0.21         | 0.45 | 0.636               |
| <i>N</i> (No. of countries)                   | 18,694 (27)           |      |                     | 18,688 (27)          |      |                     | 18,688 (27)      |      |                     | 18,616 (27)  |      |                     |

Note: Random-effects models were applied. Vaccine coverage was instrumented by the government effectiveness score and an ordinal variable for COVID-19 vaccine availability. The included common covariates not shown in the table were population density, the share of people aged 65 or over, GDP per capita, Gini index, % female population, and indicators for continent and season. Countries were categorized into three income groups based on the 2020 per capita gross national income. Standard errors were clustered at the country level.

Table S5.5 Results from mobility model: adding the number of boosters and interaction with vaccine coverage

| Y: daily mobility change (%)                      | Retail and recreation                |               |                     | Grocery and pharmacy |               |                     | Transit stations |               |                     | Workplaces |               |                     |
|---|--------------------------------------|---------------|---------------------|----------------------|---------------|---------------------|------------------|---------------|---------------------|------------|---------------|---------------------|
|   | Coef.                                | SE            | <i>P</i> > <i>z</i> | Coef.                | SE            | <i>P</i> > <i>z</i> | Coef.            | SE            | <i>P</i> > <i>z</i> | Coef.      | SE            | <i>P</i> > <i>z</i> |
| <i>Sample: all countries</i>                      |                                      |               |                     |                      |               |                     |                  |               |                     |            |               |                     |
| No. of people vaccinated (per ten people)         | 3.90                                 | 0.30          | <0.001              | 4.75                 | 0.37          | <0.001              | 3.05             | 0.35          | <0.001              | 1.54       | 0.19          | <0.001              |
| No. of boosters (per ten fully vaccinated people) | 0.96                                 | 2.23          | 0.666               | 5.06                 | 2.31          | 0.029               | -0.35            | 2.99          | 0.906               | 0.16       | 1.58          | 0.921               |
| No. of people vaccinated × No. of boosters        | -0.38                                | 0.27          | 0.162               | -1.06                | 0.31          | 0.001               | -0.27            | 0.39          | 0.495               | -0.13      | 0.21          | 0.523               |
| Stringency index                                  | -0.79                                | 0.03          | <0.001              | -0.58                | 0.04          | <0.001              | -0.77            | 0.03          | <0.001              | -0.46      | 0.02          | <0.001              |
| No. of new cases (per 10,000 people, 1 lag)       | -0.32                                | 0.08          | <0.001              | -0.03                | 0.09          | 0.735               | -0.25            | 0.08          | 0.002               | -0.11      | 0.05          | 0.026               |
|   | dy/dx                                | SE            | <i>P</i> > <i>z</i> | dy/dx                | SE            | <i>P</i> > <i>z</i> | dy/dx            | SE            | <i>P</i> > <i>z</i> | dy/dx      | SE            | <i>P</i> > <i>z</i> |
| <i>Average marginal effects</i>                   |                                      | [95% CI]      |                     |                      | [95% CI]      |                     |                  | [95% CI]      |                     |            | [95% CI]      |                     |
| No. of people vaccinated (per ten people)         | 3.80                                 | 0.31          | <0.001              | 4.47                 | 0.38          | <0.001              | 2.98             | 0.36          | <0.001              | 1.50       | 0.20          | <0.001              |
|   |                                      | [3.19, 4.41]  |                     |                      | [3.73, 5.21]  |                     |                  | [2.27, 3.70]  |                     |            | [1.12, 1.89]  |                     |
| No. of boosters (per ten fully vaccinated people) | 0.27                                 | 1.75          | 0.879               | 3.13                 | 1.78          | 0.078               | -0.84            | 2.29          | 0.715               | -0.08      | 1.21          | 0.944               |
|   |                                      | [-3.16, 3.69] |                     |                      | [-0.36, 6.61] |                     |                  | [-5.33, 3.66] |                     |            | [-2.46, 2.29] |                     |
|   | <i>N</i> ( <i>No. of countries</i> ) | 72,145 (102)  |                     |                      | 72,135 (102)  |                     |                  | 72,080 (102)  |                     |            | 72,089 (102)  |                     |

Note: Random-effects models were applied. The included common covariates not shown in the table were population density, the share of people aged 65 or over, GDP per capita, Gini index, % female population, and indicators for continent and season. Countries were categorized into three income groups based on the 2020 per capita gross national income. Standard errors were clustered at the country level. The average marginal effects were obtained by taking the derivatives of mobility with respect to corresponding predictors (dy/dx). The Delta-method was used to calculate the standard errors.

## Appendix S6 Robustness check for case growth model

For robustness check of case growth model, we replaced the case growth with the reproduction rate, obtained from Our World in Data (OWID) [1]. The results are presented in Table S6.1. The difference in vaccine coverage coefficient between the base and full models is indicated in italics. For the full model with the mobility index, the coefficient difference was  $-0.004$  ( $P = 0.006$ ). Similarly, after adjustment for mobility index and mobility in retail stores, grocery stores, and transit stations, the difference in coefficient of vaccine coverage was  $-0.007$  ( $P < 0.001$ ),  $-0.002$  ( $P = 0.024$ ), and  $-0.005$  ( $P = 0.003$ ) percentage points, respectively. In other words, mobility in retail stores, grocery stores, and transit stations attenuated vaccine effectiveness in curbing case growth by 30% (0.007/0.023), 11% (0.002/0.018), and 25% (0.005/0.02), respectively. Only workplace mobility exhibited no mediating role in the vaccine–infection relationship. These results appeared to be consistent with those from the primary models.

We further investigated whether the conclusions about vaccine-infection relationship still held, after adjusting the number different COVID-19 vaccines in the case growth model. The rationale was that, independent of the vaccine coverage, which measures the breadth (population covered), the depth (average dose number) of vaccination may also affect the case growth. To investigate the topic, we collected information on the dates of Emergency Use Listing for different vaccines approved by the World Health Organization (WHO), US Food and Drug Administration (FDA), and the European Medicines Agency (EMA). The related information is presented in Table S6.2. However, we did not find the number of individual vaccines for all 107 countries analysed in this study. The best available data source appeared to be “Covid-19 vaccine doses administered by manufacturer”, provided by Our World in Data (OWID)[2]. The dataset tracks the cumulative number of doses administered, broken down by 10 vaccine manufacturers, for 43 countries (including 27 European Union countries) per day, from as early as 4 December 2020 to the most recent date. The ten vaccines are: Pfizer/BioNTech (BNT), Moderna, Oxford/AstraZeneca (AZ), Johnson & Johnson, Sinopharm/Beijing, Sputnik V, Sinovac, Novavax, Covaxin, and CanSino. For empirical analysis, we excluded three countries (Cyprus, Iceland and Liechtenstein) that were not in the study sample, and two countries (Nepal, South Africa) for which their vaccine data by manufacturer were not available during the study period. The final sample was composed of 38 countries.

We reported the cumulative number of doses of different vaccines as of 6 February 2022 (the last day of the study period) for 38 countries in Table S6.3. In this analysis, the first day of the study period was the earliest date when the vaccine type data were available, which was approximately the first day of vaccine rollout and varied across countries. Three vaccines (Novavax, Covaxin, and CanSino) were not reported due to their low numbers. As the last row shows, BNT, Moderna, and AZ were top three vaccines, accounting for 92.1% of vaccine doses administered.

Because other vaccines were either had a relatively small number of doses, or approved at a later date, we focused on the three major vaccines. The interest was the association between daily case growth rate and the number of three different vaccines. Therefore, three corresponding variables were included in case growth model: the number of BNT, Moderna, and AZ vaccines administrated per 10 vaccinated people, respectively. For example, the number of BNT vaccines was calculated as:

$$\frac{\text{Cumulative number of BNT vaccine doses administrated in country } i \text{ on day } t}{\text{Cumulative number of people received at least one dose of COVID – 19 vaccines in country } i \text{ on day } t} \times 10$$

In line with the calculation of effective vaccine coverage in the case growth model, we used the effective vaccine number, i.e., the number from 7 days and 6 months ago for all three vaccine types. The results are presented in Table S6.4. The full models show that, the daily case growth rate decreased by 0.19-0.21 ( $P < 0.001$ ) and 0.26-0.29 percentage points ( $P < 0.005$ ) when the effective number of BNT and AZ vaccines per 10 vaccinated people increased by one, respectively.



However, the number of Moderna vaccines was not associated with the case growth after adjusting for the vaccine coverage, human mobility, the number of BNT and AZ vaccines, stringency index and a series of control variables. The results should be interpreted with caution because these were aggregated data. Due to data limitation, we did not control for other variables that could affect the effectiveness of different vaccines, such as the duration between vaccination, the timing of Emergency Use Listing, and the sequence of different vaccines received by individuals.

We examined whether the conclusion that mobility weakened the negative relationship between vaccination and case growth remained robust when the new predictors were included. As Table S6.4 shows, after adjustment for mobility in retail stores and transit stations, the difference in coefficient of vaccine coverage between the base and full models was  $-0.15$  ( $P = 0.015$ ) and  $-0.103$  ( $P = 0.026$ ) percentage points, respectively. In other words, mobility in retail stores and transit stations attenuated vaccine effectiveness in curbing case growth by 32.6% (0.15/0.46) and 24.4% (0.1/0.41), respectively. Mobility in grocery stores and workplaces exhibited no mediating role in the vaccine–infection relationship. These results suggested that the findings were similar to those from the primary models, except that mobility in grocery stores did not appear to attenuate vaccine effectiveness in 38 countries studied, where 33 were high-income.

#### References:

1. Coronavirus Pandemic. 2020. Available from: <https://ourworldindata.org/coronavirus> [accessed 19 Sep. 2022].
2. COVID-19 vaccine doses administered by manufacturer, European Union. 2023. Available from: <https://ourworldindata.org/grapher/covid-vaccine-doses-by-manufacturer> [accessed 18 Jan. 2023].

Table S6.1 Results from case growth model, using the reproduction rate as outcome

| Y: Reproduction rate                      | Coefficient | [95% CI]          | <i>P</i> > <i>z</i> |
|---|-------------|-------------------|---------------------|
| <b>Base model</b>                         |             |                   |                     |
| Effective vaccine coverage                | -0.016      | [-0.029 , -0.002] | 0.024               |
| Stringency index (14 lags)                | -0.004      | [-0.006 , -0.003] | <0.001              |
| <b>Full model, with mobility Index</b>    |             |                   |                     |
| Effective vaccine coverage                | -0.020      | [-0.034 , -0.006] | 0.005               |
| Mobility index (14 lags)                  | 0.002       | [0.001 , 0.003]   | <0.001              |
| Stringency index (14 lags)                | -0.003      | [-0.005 , -0.002] | <0.001              |
| <i>Diff. in coef. of vaccine coverage</i> | -0.004      | [-0.007 , -0.001] | 0.006               |
| <b>Full model, with retail</b>            |             |                   |                     |
| Effective vaccine coverage                | -0.023      | [-0.036 , -0.009] | 0.001               |
| Mobility: retail & recreation (14 lags)   | 0.002       | [0.002 , 0.003]   | <0.001              |
| Stringency index (14 lags)                | -0.003      | [-0.005 , -0.001] | 0.001               |
| <i>Diff. in coef. of vaccine coverage</i> | -0.007      | [-0.010 , -0.003] | <0.001              |
| <b>Full model, with grocery</b>           |             |                   |                     |
| Effective vaccine coverage                | -0.018      | [-0.031 , -0.004] | 0.011               |
| Mobility: grocery & pharmacy (14 lags)    | 0.001       | [0.000 , 0.002]   | 0.004               |
| Stringency index (14 lags)                | -0.004      | [-0.006 , -0.002] | <0.001              |
| <i>Diff. in coef. of vaccine coverage</i> | -0.002      | [-0.004 , 0.000]  | 0.024               |
| <b>Full model, with transit stations</b>  |             |                   |                     |
| Effective vaccine coverage                | -0.020      | [-0.034 , -0.006] | 0.005               |
| Mobility: transit stations (14 lags)      | 0.002       | [0.001 , 0.003]   | 0.001               |
| Stringency index (14 lags)                | -0.003      | [-0.005 , -0.002] | <0.001              |
| <i>Diff. in coef. of vaccine coverage</i> | -0.005      | [-0.008 , -0.002] | 0.003               |
| <b>Full model, with workplaces</b>        |             |                   |                     |
| Effective vaccine coverage                | -0.016      | [-0.030 , -0.002] | 0.021               |
| Mobility: workplaces (14 lags)            | 0.000       | [0.000 , 0.001]   | 0.273               |
| Stringency index (14 lags)                | -0.004      | [-0.006 , -0.003] | <0.001              |
| <i>Diff. in coef. of vaccine coverage</i> | 0.000       | [-0.001 , 0.000]  | 0.337               |

Note: The full models included mobility variables while the base model did not. Effective vaccine coverage was defined as the cumulative number of people who received at least one dose of COVID-19 vaccines per ten people from 7 days and 6 months ago. The sample was a longitudinal dataset comprising data from 107 countries with 39,450 country-days. Only the postvaccination period was used for analysis. The included common covariates not shown in the table were face-covering policies, indicators for season, Delta period, and Omicron period. Fixed-effects models were applied; standard errors were clustered at the country level.

Table S6.2 COVID-19 vaccines granted Emergency Use Listing by WHO, FDA, and EMA

| Manufacturer       | Date of Emergency Use Listing   |                                       |                                 |
|--------------------|---------------------------------|---------------------------------------|---------------------------------|
|                    | World Health Organization (WHO) | US Food and Drug Administration (FDA) | European Medicines Agency (EMA) |
| Pfizer/BioNTech    | 31 Dec. 2020                    | 11 Dec. 2020                          | 21 Dec. 2020                    |
| Oxford/AstraZeneca | 15 Feb. 2021                    | N/A                                   | 29 Jan. 2021                    |
| Moderna            | 30 Apr. 2021                    | 18 Dec. 2020                          | 6 Jan. 2021                     |
| Johnson & Johnson  | 12 Mar. 2021                    | 27 Feb 2021                           | 11 Jan. 2021                    |
| Sinopharm/Beijing  | 7 May. 2021                     | N/A                                   | N/A                             |
| Sinovac            | 1 Jun. 2021                     | N/A                                   | N/A                             |
| Covaxin            | 3 Nov. 2021                     | N/A                                   | N/A                             |
| Novavax            | 17 Dec. 2021                    | 13 Jul. 2022                          | 20 Dec. 2021                    |
| CanSino            | 19 May. 2022                    | N/A                                   | N/A                             |
| Sputnik V          | Under rolling review            | N/A                                   | Under rolling review            |

Note: Data sources for Emergency Use Listing (accessed 13 Jan. 2023) are as follows:

WHO: <https://covid19.trackvaccines.org/agency/who/>

FDA: <https://www.fda.gov/emergency-preparedness-and-response/coronavirus-disease-2019-covid-19/covid-19-vaccines>

EMA: <https://www.ema.europa.eu/en/human-regulatory/overview/public-health-threats/coronavirus-disease-covid-19/treatments-vaccines/vaccines-covid-19/covid-19-vaccines-authorized>

Table S6.3 Cumulative vaccine doses in 38 countries as of 6 February 2022, by manufacturer (unit: million)

| Country       | BNT                  | Moderna            | AZ                 | Sinovac           | Sinopharm         | J&J               | Sputnik V         |
|---------------|----------------------|--------------------|--------------------|-------------------|-------------------|-------------------|-------------------|
| Argentina     | 11,407,986           | 5,396,915          | 25,685,475         | 0                 | 27,519,764        | 0                 | 19,917,442        |
| Austria       | 14,408,585           | 1,583,345          | 1,592,840          | 0                 | 0                 | 366,989           | 0                 |
| Belgium       | 16,958,245           | 4,169,744          | 2,848,972          | 0                 | 0                 | 427,188           | 0                 |
| Bulgaria      | 2,748,000            | 478,158            | 478,514            | 0                 | 0                 | 499,873           | 0                 |
| Canada        | 53,275,635           | 22,161,502         | 2,809,644          | 0                 | 0                 | 16,921            | 0                 |
| Chile         | 7,798,839            | 0                  | 548,545            | 25,178,377        | 0                 | 0                 | 0                 |
| Croatia       | 3,859,485            | 502,770            | 568,444            | 0                 | 0                 | 198,127           | 0                 |
| Czechia       | 14,332,997           | 1,552,067          | 886,768            | 309               | 57                | 410,994           | 0                 |
| Denmark       | 10,193,073           | 1,674,290          | 155,938            | 0                 | 0                 | 46,025            | 0                 |
| Ecuador       | 8,552,679            | 0                  | 5,009,163          | 15,812,935        | 0                 | 0                 | 0                 |
| Estonia       | 1,472,792            | 228,692            | 238,906            | 0                 | 0                 | 77,289            | 0                 |
| Finland       | 9,018,975            | 1,852,227          | 553,895            | 0                 | 0                 | 0                 | 0                 |
| France        | 106,680,326          | 22,915,237         | 7,862,609          | 0                 | 0                 | 1,088,142         | 0                 |
| Germany       | 124,804,502          | 29,259,042         | 12,784,827         | 0                 | 0                 | 3,728,545         | 0                 |
| Hong Kong     | 6,979,622            | 0                  | 0                  | 4,318,547         | 0                 | 0                 | 0                 |
| Hungary       | 106,680,326          | 22,915,237         | 7,862,609          | 0                 | 0                 | 1,088,142         | 0                 |
| Ireland       | 9,264,375            | 1,045,546          | 1,252,732          | 0                 | 2,286,612         | 330,787           | 1,807,392         |
| Italy         | 7,870,659            | 1,185,023          | 1,215,315          | 0                 | 0                 | 241,277           | 0                 |
| Japan         | 177,765,742          | 34,187,148         | 116,772            | 0                 | 0                 | 0                 | 0                 |
| Latvia        | 85,053,370           | 31,779,501         | 12,169,368         | 0                 | 0                 | 1,507,429         | 0                 |
| Lithuania     | 1,568,134            | 688,632            | 262,028            | 9                 | 27                | 291,117           | 0                 |
| Luxembourg    | 3,260,506            | 326,230            | 536,489            | 0                 | 0                 | 293,416           | 0                 |
| Malta         | 688,718              | 290,706            | 105,059            | 0                 | 0                 | 41,390            | 0                 |
| Netherlands   | 693,504              | 229,625            | 227,769            | 0                 | 0                 | 32,192            | 0                 |
| Norway        | 21,438,556           | 6,257,686          | 2,473,242          | 0                 | 0                 | 752,609           | 0                 |
| Peru          | 34,505,234           | 0                  | 4,636,066          | 0                 | 19,907,081        | 0                 | 0                 |
| Poland        | 8,732,787            | 2,242,953          | 147,920            | 0                 | 0                 | 7,281             | 0                 |
| Portugal      | 37,497,535           | 3,589,959          | 5,292,114          | 0                 | 0                 | 2,643,304         | 0                 |
| Romania       | 14,566,312           | 3,335,175          | 2,270,464          | 7,429             | 3,907             | 1,136,552         | 0                 |
| Slovakia      | 12,647,268           | 995,412            | 849,551            | 0                 | 0                 | 2,024,701         | 0                 |
| Slovenia      | 5,026,530            | 670,669            | 844,164            | 0                 | 0                 | 183,252           | 37,984            |
| South Korea   | 51,987,903           | 13,439,677         | 20,323,913         | 0                 | 0                 | 1,516,502         | 0                 |
| Spain         | 2,185,165            | 232,925            | 323,098            | 0                 | 0                 | 135,792           | 0                 |
| Sweden        | 62,991,908           | 22,432,291         | 9,794,903          | 0                 | 0                 | 1,981,322         | 0                 |
| Switzerland   | 5,675,749            | 9,661,946          | 0                  | 0                 | 0                 | 58,854            | 0                 |
| Ukraine       | 14,045,627           | 2,980,084          | 4,029,295          | 9,642,922         | 0                 | 20,680            | 0                 |
| United States | 319,082,480          | 205,409,451        | 0                  | 0                 | 0                 | 18,246,402        | 0                 |
| Uruguay       | 2,275,663            | 0                  | 91,128             | 3,248,118         | 0                 | 0                 | 0                 |
| <b>Total</b>  | <b>1,377,995,792</b> | <b>455,669,865</b> | <b>136,848,539</b> | <b>58,208,646</b> | <b>49,717,448</b> | <b>39,393,094</b> | <b>21,762,818</b> |

Source: COVID-19 vaccine doses administered by manufacturer, European Union (2023). Available from: <https://ourworldindata.org/grapher/covid-vaccine-doses-by-manufacturer>. [cited 18 Jan. 2023]

Table S6.4 Results from case growth model: adding number of different COVID-19 vaccines

| Y: Case growth (%)                            | Coefficient | [95% CI]         | P>z    |
|---|-------------|------------------|--------|
| <b>Base model</b>                             |             |                  |        |
| Effective vaccine coverage                    | -0.310      | [-0.505, -0.115] | 0.002  |
| No. of BNT vaccines (per 10 vacc. people)     | -0.214      | [-0.316, -0.112] | <0.001 |
| No. of Moderna vaccines (per 10 vacc. people) | 0.074       | [-0.224, 0.372]  | 0.627  |
| No. of AZ vaccines (per 10 vacc. people)      | -0.259      | [-0.432, -0.085] | 0.003  |
| Stringency index (14 lags)                    | -0.099      | [-0.130, -0.067] | <0.001 |
| <b>Full model, with mobility Index</b>        |             |                  |        |
| Effective vaccine coverage                    | -0.397      | [-0.567, -0.227] | <0.001 |
| Mobility index (14 lags)                      | 0.040       | [0.011, 0.069]   | 0.007  |
| No. of BNT vaccines (per 10 vacc. people)     | -0.209      | [-0.312, -0.107] | <0.001 |
| No. of Moderna vaccines (per 10 vacc. people) | 0.072       | [-0.218, 0.362]  | 0.626  |
| No. of AZ vaccines (per 10 vacc. people)      | -0.279      | [-0.432, -0.126] | <0.001 |
| Stringency index (14 lags)                    | -0.081      | [-0.113, -0.048] | <0.001 |
| <i>Diff. in coef. of vaccine coverage</i>     | -0.087      | [-0.169, -0.005] | 0.038  |
| <b>Full model, with retail</b>                |             |                  |        |
| Effective vaccine coverage                    | -0.460      | [-0.638, -0.281] | <0.001 |
| Mobility: retail & recreation (14 lags)       | 0.055       | [0.023, 0.086]   | 0.001  |
| No. of BNT vaccines (per 10 vacc. people)     | -0.193      | [-0.293, -0.093] | <0.001 |
| No. of Moderna vaccines (per 10 vacc. people) | 0.067       | [-0.242, 0.375]  | 0.672  |
| No. of AZ vaccines (per 10 vacc. people)      | -0.288      | [-0.439, -0.137] | <0.001 |
| Stringency index (14 lags)                    | -0.064      | [-0.097, -0.030] | <0.001 |
| <i>Diff. in coef. of vaccine coverage</i>     | -0.150      | [-0.271, -0.030] | 0.015  |
| <b>Full model, with grocery</b>               |             |                  |        |
| Effective vaccine coverage                    | -0.350      | [-0.525, -0.175] | <0.001 |
| Mobility: grocery & pharmacy (14 lags)        | 0.019       | [0.000, 0.039]   | 0.052  |
| No. of BNT vaccines (per 10 vacc. people)     | -0.213      | [-0.314, -0.112] | <0.001 |
| No. of Moderna vaccines (per 10 vacc. people) | 0.075       | [-0.217, 0.366]  | 0.617  |
| No. of AZ vaccines (per 10 vacc. people)      | -0.271      | [-0.433, -0.110] | 0.001  |
| Stringency index (14 lags)                    | -0.093      | [-0.124, -0.062] | <0.001 |
| <i>Diff. in coef. of vaccine coverage</i>     | -0.040      | [-0.091, 0.011]  | 0.122  |
| <b>Full model, with transit stations</b>      |             |                  |        |
| Effective vaccine coverage                    | -0.413      | [-0.585, -0.241] | <0.001 |
| Mobility: transit stations (14 lags)          | 0.045       | [0.012, 0.078]   | 0.008  |
| No. of BNT vaccines (per 10 vacc. people)     | -0.200      | [-0.304, -0.096] | <0.001 |
| No. of Moderna vaccines (per 10 vacc. people) | 0.063       | [-0.232, 0.358]  | 0.676  |
| No. of AZ vaccines (per 10 vacc. people)      | -0.275      | [-0.428, -0.122] | <0.001 |
| Stringency index (14 lags)                    | -0.073      | [-0.108, -0.038] | <0.001 |
| <i>Diff. in coef. of vaccine coverage</i>     | -0.103      | [-0.195, -0.012] | 0.026  |
| <b>Full model, with workplaces</b>            |             |                  |        |
| Effective vaccine coverage                    | -0.312      | [-0.502, -0.122] | 0.001  |
| Mobility: workplaces (14 lags)                | 0.001       | [-0.015, 0.018]  | 0.859  |
| No. of BNT vaccines (per 10 vacc. people)     | -0.214      | [-0.314, -0.114] | <0.001 |
| No. of Moderna vaccines (per 10 vacc. people) | 0.074       | [-0.222, 0.371]  | 0.624  |
| No. of AZ vaccines (per 10 vacc. people)      | -0.259      | [-0.429, -0.090] | 0.003  |
| Stringency index (14 lags)                    | -0.098      | [-0.130, -0.066] | <0.001 |
| <i>Diff. in coef. of vaccine coverage</i>     | -0.002      | [-0.028, 0.023]  | 0.861  |

Note: The full models included mobility variables while the base model did not. Effective vaccine coverage was defined as the cumulative number of people who received at least one dose of COVID-19 vaccines per ten people from 7 days and 6 months ago. Number of BNT/Moderna/AZ vaccines was defined as the number of BNT/ Moderna/AZ vaccine doses administered per 10 vaccinated people. The sample was a longitudinal dataset comprising data from 38 countries (including 27 European Union countries) and had 7,426 country-days. Only the postvaccination period was used for analysis. The included common covariates not shown in the table were face-covering policies, indicators for season, Delta period, and Omicron period. Fixed-effects models were applied; standard errors were clustered at the country level. Abbreviations: BNT=Pfizer/BioNTech; AZ=Oxford/AstraZeneca; vacc.=vaccinated.

**Appendix S7 Mobility model: adding interactions between vaccine coverage rate and stage of vaccination**

Table S7 Results from mobility model: adding interactions between vaccine coverage rate and stage of vaccination

| Y: daily mobility change (%)                  | Retail and recreation |      |        | Grocery and pharmacy |      |        | Transit stations |      |        | Workplaces   |      |        |
|---|-----------------------|------|--------|----------------------|------|--------|------------------|------|--------|--------------|------|--------|
|   | Coef.                 | SE   | P>z    | Coef.                | SE   | P>z    | Coef.            | SE   | P>z    | Coef.        | SE   | P>z    |
| <b>Panel A: all countries</b>                 |                       |      |        |                      |      |        |                  |      |        |              |      |        |
| No. of people vaccinated (per ten people)     |                       |      |        |                      |      |        |                  |      |        |              |      |        |
| × Stage 1                                     | 10.83                 | 1.53 | <0.001 | 19.17                | 2.08 | <0.001 | 10.70            | 1.39 | <0.001 | 3.51         | 0.87 | <0.001 |
| × Stage 2                                     | 5.93                  | 0.56 | <0.001 | 8.92                 | 0.69 | <0.001 | 5.32             | 0.59 | <0.001 | 2.63         | 0.38 | <0.001 |
| × Stage 3                                     | 3.98                  | 0.30 | <0.001 | 5.32                 | 0.34 | <0.001 | 3.51             | 0.46 | <0.001 | 1.37         | 0.19 | <0.001 |
| × Stage 4                                     | 3.57                  | 0.31 | <0.001 | 4.01                 | 0.38 | <0.001 | 2.48             | 0.31 | <0.001 | 1.41         | 0.21 | <0.001 |
| × Stage 5                                     | 2.55                  | 0.27 | <0.001 | 2.73                 | 0.34 | <0.001 | 1.87             | 0.32 | <0.001 | 0.83         | 0.22 | <0.001 |
| Stringency index                              | -0.77                 | 0.03 | <0.001 | -0.56                | 0.04 | <0.001 | -0.75            | 0.03 | <0.001 | -0.46        | 0.02 | <0.001 |
| No. of new cases (per 10,000 people, 1 lag)   | -0.45                 | 0.09 | <0.001 | -0.21                | 0.08 | 0.009  | -0.43            | 0.08 | <0.001 | -0.16        | 0.05 | 0.001  |
| <i>N</i> (No. of countries)                   | 75,643 (107)          |      |        | 75,633 (107)         |      |        | 75,578 (107)     |      |        | 75,587 (107) |      |        |
| <b>Panel B: high income countries</b>         |                       |      |        |                      |      |        |                  |      |        |              |      |        |
| No. of people vaccinated (per ten people)     |                       |      |        |                      |      |        |                  |      |        |              |      |        |
| × Stage 1                                     | 5.75                  | 1.09 | <0.001 | 10.74                | 1.21 | <0.001 | 6.26             | 1.22 | <0.001 | 5.36         | 0.97 | <0.001 |
| × Stage 2                                     | 4.60                  | 0.52 | <0.001 | 6.27                 | 0.55 | <0.001 | 4.22             | 0.59 | <0.001 | 2.51         | 0.39 | <0.001 |
| × Stage 3                                     | 3.28                  | 0.32 | <0.001 | 4.45                 | 0.38 | <0.001 | 3.03             | 0.63 | <0.001 | 1.10         | 0.18 | <0.001 |
| × Stage 4                                     | 2.66                  | 0.31 | <0.001 | 2.95                 | 0.31 | <0.001 | 1.71             | 0.32 | <0.001 | 0.93         | 0.23 | <0.001 |
| × Stage 5                                     | 2.21                  | 0.30 | <0.001 | 2.69                 | 0.40 | <0.001 | 1.85             | 0.38 | <0.001 | 0.75         | 0.25 | 0.003  |
| Stringency index                              | -0.73                 | 0.04 | <0.001 | -0.36                | 0.04 | <0.001 | -0.64            | 0.04 | <0.001 | -0.44        | 0.03 | <0.001 |
| No. of new cases (per 10,000 people, 1 lag)   | -0.29                 | 0.08 | <0.001 | -0.17                | 0.05 | 0.001  | -0.33            | 0.07 | <0.001 | -0.10        | 0.04 | 0.021  |
| <i>N</i> (No. of countries)                   | 35,582 (50)           |      |        | 35,576 (50)          |      |        | 35,557 (50)      |      |        | 35,579 (50)  |      |        |
| <b>Panel C: upper-middle income countries</b> |                       |      |        |                      |      |        |                  |      |        |              |      |        |
| No. of people vaccinated (per ten people)     |                       |      |        |                      |      |        |                  |      |        |              |      |        |
| × Stage 1                                     | 14.00                 | 3.09 | <0.001 | 22.07                | 4.44 | <0.001 | 14.19            | 2.75 | <0.001 | 2.75         | 1.62 | 0.090  |
| × Stage 2                                     | 5.94                  | 1.02 | <0.001 | 9.29                 | 1.07 | <0.001 | 5.22             | 1.07 | <0.001 | 1.93         | 0.71 | 0.006  |
| × Stage 3                                     | 4.04                  | 0.65 | <0.001 | 5.55                 | 0.61 | <0.001 | 3.68             | 0.80 | <0.001 | 1.44         | 0.38 | <0.001 |
| × Stage 4                                     | 5.22                  | 0.65 | <0.001 | 5.86                 | 0.62 | <0.001 | 4.14             | 0.56 | <0.001 | 2.40         | 0.43 | <0.001 |
| × Stage 5                                     | 4.31                  | 0.83 | <0.001 | 4.27                 | 0.83 | <0.001 | 3.23             | 0.60 | <0.001 | 1.35         | 0.79 | 0.088  |

|   |             |      |        |             |      |        |             |      |        |             |      |        |
|---|-------------|------|--------|-------------|------|--------|-------------|------|--------|-------------|------|--------|
| Stringency index                              | -0.68       | 0.04 | <0.001 | -0.51       | 0.05 | <0.001 | -0.72       | 0.05 | <0.001 | -0.45       | 0.03 | <0.001 |
| No. of new cases (per 10,000 people, 1 lag)   | -0.74       | 0.18 | <0.001 | -0.09       | 0.17 | 0.621  | -0.72       | 0.17 | <0.001 | -0.34       | 0.14 | 0.017  |
| <i>N (No. of countries)</i>                   | 21,074 (30) |      |        | 21,076 (30) |      |        | 21,040 (30) |      |        | 21,112 (30) |      |        |
| <b>Panel D: lower-middle income countries</b> |             |      |        |             |      |        |             |      |        |             |      |        |
| No. of people vaccinated (per ten people)     |             |      |        |             |      |        |             |      |        |             |      |        |
| × Stage 1                                     | 15.15       | 3.43 | <0.001 | 23.60       | 4.27 | <0.001 | 11.87       | 2.99 | <0.001 | 2.30        | 2.17 | 0.291  |
| × Stage 2                                     | 9.22        | 1.48 | <0.001 | 12.56       | 1.88 | <0.001 | 7.60        | 1.71 | <0.001 | 4.24        | 0.99 | <0.001 |
| × Stage 3                                     | 5.80        | 0.72 | <0.001 | 7.86        | 0.95 | <0.001 | 4.58        | 0.81 | <0.001 | 2.30        | 0.68 | 0.001  |
| × Stage 4                                     | 5.57        | 0.71 | <0.001 | 7.45        | 1.25 | <0.001 | 4.17        | 0.89 | <0.001 | 2.60        | 0.59 | <0.001 |
| × Stage 5                                     | 3.62        | 0.25 | <0.001 | 3.03        | 0.76 | <0.001 | 1.34        | 0.37 | <0.001 | 0.56        | 0.14 | <0.001 |
| Stringency index                              | -0.85       | 0.06 | <0.001 | -0.84       | 0.07 | <0.001 | -0.90       | 0.08 | <0.001 | -0.50       | 0.06 | <0.001 |
| No. of new cases (per 10,000 people, 1 lag)   | -0.17       | 0.46 | 0.717  | 1.23        | 0.53 | 0.021  | 0.53        | 0.54 | 0.324  | 0.25        | 0.31 | 0.408  |
| <i>N (No. of countries)</i>                   | 18,987 (27) |      |        | 18,981 (27) |      |        | 18,981 (27) |      |        | 18,896 (27) |      |        |

Note: Vaccination stage was determined on the basis of the proportion of the population receiving at least one dose of COVID-19 vaccines: above 0 and  $\leq 20\%$  (Stage 1), 20%–40% (Stage 2), 40%–60% (Stage 3), 60%–80% (Stage 4), and  $\geq 80\%$  (Stage 5); the reference stage is the prevaccination period. This table was used to produce Figure 2 in the main text. Random-effects models were applied. The included common covariates not shown in the table were population density, the share of people aged 65 or over, GDP per capita, Gini index, % female population, and indicators for continent and season. Standard errors were clustered at the country level.



## Appendix S8 Applying false-positive corrections to mobility and case growth models

In order to reduce the likelihood of false rejections in our models, we employed Anderson's method and calculated the False Discovery Rate (FDR)  $q$ -values [1]. It is the ratio of the number of false positive results to the number of total positive test results. Anderson's method takes  $P$ -values as inputs as in a Bonferroni adjustment, and has greater power than other alternatives [2].

The adjusted  $P$ -values, or  $Q$ -values, are presented in Table S8.1 for key covariates in the mobility model, and in Table S8.2 for the case growth model. The results showed that most of the adjusted  $P$ -values were larger than the original  $P$ -values. However, they were still very small, with all of the adjusted  $P$ -values for vaccine coverage smaller than 0.005. Therefore, the conclusions drawn from the original models remained robust. It is noteworthy that some adjusted  $P$ -values were actually less than the original values (9 out of 48 in Table S8.1 and 1 out of 17 in Table S8.2). The reason for this is that if there are many true rejections, one can tolerate several false rejections and still keep the false discovery rate low [1, 2].

### Reference:

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Table S8.1 Results of applying false-positive correction to mobility model presented in Table 3

| Y: daily mobility change (%)                  | Retail and recreation |                     |               | Grocery and pharmacy |                     |               | Transit stations |                     |               | Workplaces   |                     |               |
|---|-----------------------|---------------------|---------------|----------------------|---------------------|---------------|------------------|---------------------|---------------|--------------|---------------------|---------------|
|   | Coef.                 | <i>P</i> > <i>z</i> | Adj. <i>P</i> | Coef.                | <i>P</i> > <i>z</i> | Adj. <i>P</i> | Coef.            | <i>P</i> > <i>z</i> | Adj. <i>P</i> | Coef.        | <i>P</i> > <i>z</i> | Adj. <i>P</i> |
| <b>Panel A: all countries</b>                 |                       |                     |               |                      |                     |               |                  |                     |               |              |                     |               |
| No. of people vaccinated (per ten people)     | 3.59                  | 0.000000000         | 0.001         | 4.28                 | 0.000000000         | 0.001         | 2.72             | 0.000000000         | 0.001         | 1.38         | 0.000000000         | 0.001         |
| Stringency index                              | -0.78                 | 0.000000000         | 0.001         | -0.57                | 0.000000000         | 0.001         | -0.76            | 0.000000000         | 0.001         | -0.46        | 0.000000000         | 0.001         |
| No. of new cases (per 10,000 people, 1 lag)   | -0.46                 | 0.637928200         | 0.057         | -0.24                | 0.006485000         | 0.002         | -0.45            | 0.000000109         | 0.001         | -0.17        | 0.000764000         | 0.001         |
| <i>N</i> (No. of countries)                   | 75,643 (107)          |                     |               | 75,633 (107)         |                     |               | 75,578 (107)     |                     |               | 75,587 (107) |                     |               |
| <b>Panel B: high income (HI) countries</b>    |                       |                     |               |                      |                     |               |                  |                     |               |              |                     |               |
| No. of people vaccinated (per ten people)     | 2.73                  | 0.000000000         | 0.001         | 3.24                 | 0.000000000         | 0.001         | 2.03             | 0.000000000         | 0.001         | 0.96         | 0.000000000         | 0.001         |
| Stringency index                              | -0.72                 | 0.000000000         | 0.001         | -0.33                | 0.000000000         | 0.001         | -0.63            | 0.000000000         | 0.001         | -0.43        | 0.000000000         | 0.001         |
| No. of new cases (per 10,000 people, 1 lag)   | -0.31                 | 0.000093951         | 0.001         | -0.21                | 0.000239209         | 0.001         | -0.36            | 0.000000362         | 0.001         | -0.1         | 0.012870721         | 0.002         |
| <i>N</i> (No. of countries)                   | 35,582 (50)           |                     |               | 35,576 (50)          |                     |               | 35,557 (50)      |                     |               | 35,579 (50)  |                     |               |
| <b>Panel C: upper-middle income countries</b> |                       |                     |               |                      |                     |               |                  |                     |               |              |                     |               |
| No. of people vaccinated (per ten people)     | 4.93                  | 0.000000000         | 0.001         | 5.98                 | 0.000000000         | 0.001         | 4.05             | 0.000000000         | 0.001         | 2.07         | 0.000000000         | 0.001         |
| Stringency index                              | -0.69                 | 0.000000000         | 0.001         | -0.56                | 0.000000000         | 0.001         | -0.74            | 0.000000000         | 0.001         | -0.45        | 0.000000000         | 0.001         |
| No. of new cases (per 10,000 people, 1 lag)   | -0.65                 | 0.001105221         | 0.001         | 0.14                 | 0.458328109         | 0.04          | -0.61            | 0.000340073         | 0.001         | -0.39        | 0.012747099         | 0.003         |
| <i>N</i> (No. of countries)                   | 21,074 (30)           |                     |               | 21,076 (30)          |                     |               | 21,040 (30)      |                     |               | 21,112 (30)  |                     |               |
| <b>Panel D: lower-middle income countries</b> |                       |                     |               |                      |                     |               |                  |                     |               |              |                     |               |
| No. of people vaccinated (per ten people)     | 6.00                  | 0.000000000         | 0.001         | 7.90                 | 0.000000637         | 0.001         | 4.50             | 0.000000637         | 0.001         | 2.54         | 0.000000000         | 0.001         |
| Stringency index                              | -0.89                 | 0.000000000         | 0.001         | -0.9                 | 0.000000000         | 0.001         | -0.93            | 0.000000000         | 0.001         | -0.5         | 0.000000000         | 0.001         |
| No. of new cases (per 10,000 people, 1 lag)   | -0.20                 | 0.637928219         | 0.19          | 1.24                 | 0.021073331         | 0.01          | 0.52             | 0.334360972         | 0.112         | 0.27         | 0.454832788         | 0.142         |
| <i>N</i> (No. of countries)                   | 18,987 (27)           |                     |               | 18,981 (27)          |                     |               | 18,981 (27)      |                     |               | 18,896 (27)  |                     |               |

Note: The adjusted *P*-values are the False Discovery Rate (FDR) *Q*-values computed using Anderson's code, available at: [https://are.berkeley.edu/~mlanderson/downloads/fdr\\_sharpened\\_qvalues.do.zip](https://are.berkeley.edu/~mlanderson/downloads/fdr_sharpened_qvalues.do.zip).

Table S8.2 Results of applying false-positive correction to case growth model presented in Figure 3

| <b>Base model</b>                        | Coef. | [95% Conf. Int.] |       | $P>z$         | Adj. $P$ -value |
|--|-------|------------------|-------|---------------|-----------------|
| Effective vaccine coverage               | -0.28 | -0.43            | -0.13 | 0.00039359875 | 0.001           |
| Stringency index (14 lags)               | -0.10 | -0.12            | -0.07 | 0.00000000001 | 0.001           |
| <b>Full model, with mobility Index</b>   |       |                  |       |               |                 |
| Effective vaccine coverage               | -0.38 | -0.55            | -0.21 | 0.00002106045 | 0.001           |
| Mobility index (14 lags)                 | 0.05  | 0.03             | 0.07  | 0.00000343197 | 0.001           |
| Stringency index (14 lags)               | -0.08 | -0.10            | -0.05 | 0.00000000372 | 0.001           |
| <b>Full model, with retail</b>           |       |                  |       |               |                 |
| Effective vaccine coverage               | -0.42 | -0.59            | -0.25 | 0.00000400288 | 0.001           |
| Mobility: retail & recreation (14 lags)  | 0.05  | 0.04             | 0.07  | 0.00000000520 | 0.001           |
| Stringency index (14 lags)               | -0.07 | -0.09            | -0.04 | 0.00000014390 | 0.001           |
| <b>Full model, with grocery</b>          |       |                  |       |               |                 |
| Effective vaccine coverage               | -0.33 | -0.49            | -0.18 | 0.00006978839 | 0.001           |
| Mobility: grocery & pharmacy (14 lags)   | 0.03  | 0.01             | 0.04  | 0.00004950538 | 0.001           |
| Stringency index (14 lags)               | -0.09 | -0.11            | -0.06 | 0.00000000006 | 0.001           |
| <b>Full model, with transit stations</b> |       |                  |       |               |                 |
| Effective vaccine coverage               | -0.38 | -0.55            | -0.22 | 0.00001958263 | 0.001           |
| Mobility: transit stations (14 lags)     | 0.04  | 0.02             | 0.07  | 0.00013195299 | 0.001           |
| Stringency index (14 lags)               | -0.07 | -0.10            | -0.05 | 0.00000005759 | 0.001           |
| <b>Full model, with workplaces</b>       |       |                  |       |               |                 |
| Effective vaccine coverage               | -0.30 | -0.46            | -0.15 | 0.00022243816 | 0.001           |
| Mobility: workplaces (14 lags)           | 0.02  | 0.00             | 0.03  | 0.01410526340 | 0.001           |
| Stringency index (14 lags)               | -0.09 | -0.11            | -0.07 | 0.00000000001 | 0.001           |

Note: the adjusted  $P$ -values are the False Discovery Rate (FDR)  $Q$ -values computed using Anderson's code, available at: [https://are.berkeley.edu/~mlanderson/downloads/fdr\\_sharpened\\_qvalues.do.zip](https://are.berkeley.edu/~mlanderson/downloads/fdr_sharpened_qvalues.do.zip).

## **Appendix S9 Mobility model: adding country socioeconomic development status (SDS) as moderators**

To explore socioeconomic factors that may change the relationship between vaccine coverage and human mobility, we focused on eight nonmonetary measures of socioeconomic development status (SDS) in four dimensions: human capital, social capital, employment, and digitalization. The measurement, definition and data sources are summarised in Table S9.1. The hypothesis is that, compared with countries with lower SDS, those with higher SDS may be more likely to maintain social distancing after COVID-19 vaccination.

The first dimension, education, is closely related to a country's human capital. Education is also a key dimension of human development, and could affect human behaviour [1]. For this dimension, we used the secondary rather than primary school enrolment, because it had a larger variation across countries than primary school enrolment did. The second dimension, social capital, is defined as “networks together with shared norms, values and understandings that facilitate cooperation within or among groups” [2]. The World Bank similarly describes social capital as “the institutions, relationships, and norms that shape the quality and quantity of a society's social interactions” [3]. Social capital is likely to contribute to collective preventive behaviour, where trust is a key element. Especially, in the absence of lockdown policies, social cohesion could foster compliance of social distancing. We focused on trust science and trust people in neighbourhood, since these factors may influence decisions on social distancing.

The third dimension considered different occupation and employment status. Level of required physical attendance varied across occupation, which may lead to varying degrees of mobility. Self-employed work status has been widely used to describe workers' behaviour and socioeconomic groups [4]. A sizeable self-employed workers could be an indication of a large agriculture sector and low growth of formal economy [4]. Finally, we included the dimension of digitalization because people with better digital capability may be more able to maintain physical and social distancing in daily life.

We calculated the mean value of individual SDS variables for individual income groups. The results are presented in Table S9.2. Jame's test [5] rejected the null hypothesis that the mean is equal across income group. Compared with lower- and upper-middle income countries, high-income countries appeared to have a higher enrolment ratio, higher trust, a larger share of employment in the industry and service sector, a much smaller share of workers in the agriculture sector and self-employed status, and a substantially larger share of individuals using the internet. Some countries did not report related data. Therefore, the sample size decreased from 107 to 79 and 91 countries for school enrolment and trust, respectively.

We added eight SDS variables to the mobility model one-by-one and re-ran the regression. To investigate whether they were moderators, an interaction term between the SDS and the vaccine coverage, was included. The results were presented in Table S9.3. The random-effect model showed that the interaction was statistically significant ( $P < 0.001$ ) for all SDS in all four location categories, suggesting that the magnitude of vaccination-induced mobility (VM) varied with SDS.

To understand the association of vaccine coverage with mobility at different values of SDS, we estimated the average marginal effect of vaccine coverage at the 10<sup>th</sup>, 30<sup>th</sup>, 50<sup>th</sup>, 70<sup>th</sup> and 90<sup>th</sup> percentile of distribution of each SDS. The results are displayed in Table S9.4. Consider, for example, the first column of school enrolment. The interpretation of  $dy/dx$  was that, when the enrolment ratio was 45.6%, 54.5%, 61.7%, 73.6% and 78.9%, a 10 percentage points increase in vaccine coverage was associated with a 5.58, 4.18, 3.81, 3.58 and 2.52 percentage points ( $P < 0.001$ ) increase in the number of visitors to retail stores, respectively. The most substantial difference in the marginal effect was observed for digitalization. The VM in grocery stores was 11.36 and 2.08 percentage points, respectively, when the share of internet users shifted from the 10<sup>th</sup> to the 90<sup>th</sup> percentile of the distribution. This result implied the critical role of digital capability to hold back human mobility after vaccination. In sum, the key findings are that, the magnitude of VM were smaller for countries with

higher school enrolment ratios, trust in science, or trust in people; larger shares of employment in industry or service sectors or internet users, and smaller shares of agriculture employment or self-employed. Overall, the marginal effect analysis supported our conjecture that countries with higher SDS had lower VM.

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5. James GS. Tests of linear hypotheses in univariate and multivariate analysis when the ratios of the population variances are unknown. *Biometrika*. 1954;41:19-43.

**Table S9.1 Summary of variables for country socioeconomic development status**

|   | Measurement                           | Definition  |
|---|---------------------------------------|---|
| <b>I. Human capital<sup>a</sup></b>         |                                       |   |
| School enrolment, secondary                 | % gross                               | The ratio of total enrolment (regardless of age), to the population of the age group that officially corresponds to the level of education. The ratio includes overage and underage students.   |
| <b>II. Social capital<sup>b</sup></b>       |                                       |   |
| Trust science                               | From 0 (low) to 100 (high)            | Survey questions: "How much do you trust each of the following: other people in your neighbourhood; your national government; scientists; journalists; doctors and nurses; people who work at non-governmental or non-profit organizations; healers? Do you trust them a lot, some, not much, or not at all?" |
| Trust people in neighbourhood               | From 0 (low) to 100 (high)            |   |
| <b>III. Employment<sup>c</sup></b>          |                                       |   |
| Employment in industry                      | From 0 to 100 (% of total employment) | The industry sector consists of: mining and quarrying; manufacturing; construction; public utilities (electricity, gas, and water).   |
| Employment in service                       | From 0 to 100 (% of total employment) | The services sector consists of:<br>1. Wholesale, retail trade, restaurants and hotels<br>2. Transport, storage, and communications<br>3. Financing, insurance, real estate, and business services<br>4. Community, social, and personal services   |
| Employment in agriculture                   | From 0 to 100 (% of total employment) | The agriculture sector consists of activities in agriculture, hunting, forestry and fishing,  |
| Self-employed                               | From 0 to 100 (% of total employment) | Self-employed workers are those workers who, working on their own account or with one or a few partners or in cooperative, hold the type of jobs defined as a "self-employment jobs.", such as contributing family workers.   |
| <b>IV. Digitalization</b>                   |                                       |   |
| Individuals using the internet <sup>d</sup> | From 0 to 100 (% of population)       | Internet users are individuals who have used the Internet (from any location) in the last 3 months, via a computer, mobile phone, personal digital assistant, games machine, digital TV etc.  |

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c. International Labour Organization. "ILO modelled estimates database" ILOSTAT. Data source: <https://ilostat.ilo.org/data/> [accessed 22 Jan. 2023].

d. International Telecommunication Union World Telecommunication/ICT Indicators Database. Data source: <https://data.worldbank.org/indicator/IT.NET.USER.ZS> [accessed 22 Jan. 2023].

**Table S9.2 Mean value for country socioeconomic development status (SDS), by income group**

| <b>Income group \ SDS</b>              | <b>School enrolment, secondary (% gross)</b>       | <b>Trust Science (0-100)</b>                       | <b>Trust people in neighbourhood (0-100)</b>       | <b>Employment in industry (% of total employment)</b> | <b>Employment in services (% of total employment)</b> | <b>Employment in agriculture (% of total employment)</b> | <b>Self-employed (% of total employment)</b>        | <b>Individuals using the internet (% of population)</b> |
|--|--|--|--|---|---|--|---|---|
| <b>High income</b>                     | 112.7  | 87.3   | 79.9   | 23.6  | 72.1  | 4.3  | 15.1  | 85.4  |
| <b>Upper-middle income</b>             | 98.5   | 70.7   | 63.3   | 21.5  | 61.5  | 17.0   | 31.8  | 65.9  |
| <b>Lower-middle income</b>             | 74.6   | 73.7   | 68.5   | 19.1  | 44.4  | 36.5   | 56.1  | 38.1  |
| Test for equality of three group means | $\chi^2(2) = 40095.4;$<br>Prob $> \chi^2 = 0.0000$ | $\chi^2(2) = 45629.1;$<br>Prob $> \chi^2 = 0.0000$ | $\chi^2(2) = 29974.5;$<br>Prob $> \chi^2 = 0.0000$ | $\chi^2(2) = 5273.4;$<br>Prob $> \chi^2 = 0.0000$     | $\chi^2(2) = 95987.8;$<br>Prob $> \chi^2 = 0.0000$    | $\chi^2(2) = 128985.6;$<br>Prob $> \chi^2 = 0.0000$      | $\chi^2(2) = 115712.0;$<br>Prob $> \chi^2 = 0.0000$ | $\chi^2(2) = 177572.9;$<br>Prob $> \chi^2 = 0.0000$     |
| Year                                   | 2018   | 2020   | 2020   | 2018  | 2018  | 2018   | 2018  | 2018  |
| No. of countries                       | 79   | 91   | 91   | 106   | 106   | 106  | 106   | 102   |

Note: Jame's test which allows heterogeneous covariance matrices across income groups was conducted.

**Table S9.3 Results from mobility model: adding SDS and interaction with vaccine coverage**

| <b>Y: daily mobility change (%)</b>                       | <b>Retail &amp; recreation</b> | <b>Grocery &amp; pharmacy</b> | <b>Transit stations</b> | <b>Workplaces</b> |
|---|--------------------------------|-------------------------------|-------------------------|-------------------|
|   | Coef.                          | Coef.                         | Coef.                   | Coef.             |
| No. of people vaccinated (per ten people)                 | 9.74***                        | 14.07***                      | 10.21***                | 5.13***           |
| School enrolment ratio (secondary, % gross)               | 0.01                           | 0.07                          | -0.05                   | -0.03             |
| No. of people vaccinated × School enrolment ratio         | -0.06***                       | -0.09***                      | -0.07***                | -0.04***          |
| <i>N</i>  | 56,113                         | 56,116                        | 56,129                  | 56,126            |
| No. of people vaccinated (per ten people)                 | 13.41***                       | 20.20***                      | 13.76***                | 7.83***           |
| Trust science   | -0.10                          | 0.06                          | -0.07                   | 0.13              |
| No. of people vaccinated × Trust science                  | -0.12***                       | -0.19***                      | -0.13***                | -0.08***          |
| <i>N</i>  | 64,470                         | 64,484                        | 64,464                  | 64,404            |
| No. of people vaccinated (per ten people)                 | 10.51***                       | 15.23***                      | 10.91***                | 6.56***           |
| Trust people in neighbourhood                             | -0.01                          | 0.12                          | -0.11                   | 0.12              |
| No. of people vaccinated × Trust people in neighbourhood  | -0.09***                       | -0.15***                      | -0.11***                | -0.07***          |
| <i>N</i>  | 64,470                         | 64,484                        | 64,464                  | 64,404            |
| No. of people vaccinated (per ten people)                 | 5.43***                        | 5.98***                       | 3.79***                 | 2.46***           |
| Employment in industry                                    | -0.13                          | 0.42                          | -0.01                   | 0.10              |
| No. of people vaccinated × Employment in industry         | -0.08**                        | -0.07*                        | -0.04                   | -0.05**           |
| <i>N</i>  | 75,005                         | 74,995                        | 74,940                  | 74,949            |
| No. of people vaccinated (per ten people)                 | 9.25***                        | 13.55***                      | 8.28***                 | 4.15***           |
| Employment in service                                     | 0.14                           | 0.22                          | -0.05                   | -0.13             |
| No. of people vaccinated × Employment in service          | -0.08***                       | -0.14***                      | -0.08**                 | -0.04*            |
| <i>N</i>  | 75,005                         | 74,995                        | 74,940                  | 74,949            |
| No. of people vaccinated (per ten people)                 | 2.37***                        | 2.42***                       | 1.62***                 | 0.75***           |
| Employment in agriculture                                 | -0.06                          | -0.27                         | 0.07                    | 0.10              |
| No. of people vaccinated × Employment in agriculture      | 0.12***                        | 0.18***                       | 0.11**                  | 0.06**            |
| <i>N</i>  | 75,005                         | 74,995                        | 74,940                  | 74,949            |
| No. of people vaccinated (per ten people)                 | 1.40***                        | 1.08*                         | 0.77                    | 0.19              |
| Self-employment   | -0.08                          | -0.13                         | 0.03                    | 0.03              |
| No. of people vaccinated × Self-employment                | 0.09***                        | 0.14***                       | 0.08***                 | 0.05***           |
| <i>N</i>  | 75,005                         | 74,995                        | 74,940                  | 74,949            |
| No. of people vaccinated (per ten people)                 | 11.51***                       | 16.30***                      | 10.17***                | 5.58***           |
| Individuals using the internet                            | -0.01                          | 0.03                          | -0.08                   | -0.11             |
| No. of people vaccinated × Individuals using the internet | -0.10***                       | -0.15***                      | -0.10***                | -0.05***          |
| <i>N</i>  | 72,195                         | 72,185                        | 72,130                  | 72,139            |

Note: Random-effects models were applied. The included common covariates not shown in the table were stringency index, risk information (as measured by the lagged number of new cases), population density, the share of people aged 65 or over, GDP per capita, Gini index, % female population, and indicators for continent and season. Standard errors were clustered at the country level.

Legend: \*  $P < 0.05$ ; \*\*  $P < 0.01$ ; \*\*\*  $P < 0.001$



**Table S9.4 Average marginal effects of vaccine coverage on mobility, at different values of SDS**

| Y: daily mobility change (%)               | Retail and recreation |      |        | Grocery and pharmacy |      |        | Transit stations |      |        | Workplaces |      |        |
|--|-----------------------|------|--------|----------------------|------|--------|------------------|------|--------|------------|------|--------|
|  | dy/dx                 | SE   | P>z    | dy/dx                | SE   | P>z    | dy/dx            | SE   | P>z    | dy/dx      | SE   | P>z    |
| No. of people vaccinated (per ten people)  |                       |      |        |                      |      |        |                  |      |        |            |      |        |
| at:  |                       |      |        |                      |      |        |                  |      |        |            |      |        |
| School enrolment ratio =45.6 (p10)         | 5.58                  | 0.62 | <0.001 | 7.38                 | 0.71 | <0.001 | 5.17             | 0.58 | <0.001 | 2.58       | 0.43 | <0.001 |
| School enrolment ratio =54.5 (p30)         | 4.18                  | 0.32 | <0.001 | 5.13                 | 0.38 | <0.001 | 3.48             | 0.34 | <0.001 | 1.72       | 0.22 | <0.001 |
| School enrolment ratio =61.7 (p50)         | 3.81                  | 0.27 | <0.001 | 4.53                 | 0.32 | <0.001 | 3.02             | 0.30 | <0.001 | 1.49       | 0.18 | <0.001 |
| School enrolment ratio =73.6 (p70)         | 3.58                  | 0.25 | <0.001 | 4.17                 | 0.30 | <0.001 | 2.75             | 0.28 | <0.001 | 1.35       | 0.16 | <0.001 |
| School enrolment ratio =78.9 (p90)         | 2.52                  | 0.35 | <0.001 | 2.46                 | 0.38 | <0.001 | 1.47             | 0.32 | <0.001 | 0.70       | 0.19 | 0.001  |
|  | dy/dx                 | SE   | P>z    | dy/dx                | SE   | P>z    | Coef.            | SE   | P>z    | dy/dx      | SE   | P>z    |
| No. of people vaccinated (per ten people)  |                       |      |        |                      |      |        |                  |      |        |            |      |        |
| at:  |                       |      |        |                      |      |        |                  |      |        |            |      |        |
| Trust Science = 64.1 (p10)                 | 5.85                  | 0.71 | <0.001 | 7.95                 | 0.99 | <0.001 | 5.29             | 0.73 | <0.001 | 2.83       | 0.48 | <0.001 |
| Trust Science = 75.9 (p30)                 | 4.46                  | 0.37 | <0.001 | 5.69                 | 0.52 | <0.001 | 3.73             | 0.40 | <0.001 | 1.91       | 0.25 | <0.001 |
| Trust Science = 80.8 (p50)                 | 3.88                  | 0.26 | <0.001 | 4.75                 | 0.37 | <0.001 | 3.08             | 0.31 | <0.001 | 1.52       | 0.17 | <0.001 |
| Trust Science = 86.2 (p70)                 | 3.24                  | 0.22 | <0.001 | 3.72                 | 0.31 | <0.001 | 2.37             | 0.30 | <0.001 | 1.02       | 0.15 | <0.001 |
| Trust Science = 93.4 (p90)                 | 2.39                  | 0.34 | <0.001 | 2.34                 | 0.46 | <0.001 | 1.42             | 0.43 | <0.001 | 0.54       | 0.22 | 0.002  |
|  | dy/dx                 | SE   | P>z    | dy/dx                | SE   | P>z    | dy/dx            | SE   | P>z    | dy/dx      | SE   | P>z    |
| No. of people vaccinated (per ten people)  |                       |      |        |                      |      |        |                  |      |        |            |      |        |
| at:  |                       |      |        |                      |      |        |                  |      |        |            |      |        |
| Trust People in neighbourhood = 55.2 (p10) | 5.41                  | 0.49 | <0.001 | 7.17                 | 0.62 | <0.001 | 4.90             | 0.57 | <0.001 | 2.70       | 0.28 | <0.001 |
| Trust People in neighbourhood = 66.3 (p30) | 4.39                  | 0.30 | <0.001 | 5.55                 | 0.40 | <0.001 | 3.69             | 0.36 | <0.001 | 1.93       | 0.18 | <0.001 |
| Trust People in neighbourhood = 74.2 (p50) | 3.66                  | 0.22 | <0.001 | 4.39                 | 0.31 | <0.001 | 2.83             | 0.27 | <0.001 | 1.38       | 0.14 | <0.001 |
| Trust People in neighbourhood = 81.1 (p70) | 3.02                  | 0.24 | <0.001 | 3.38                 | 0.32 | <0.001 | 2.08             | 0.28 | <0.001 | 0.90       | 0.15 | <0.001 |
| Trust People in neighbourhood = 87.9 (p90) | 2.39                  | 0.33 | <0.001 | 2.39                 | 0.41 | <0.001 | 1.34             | 0.36 | <0.001 | 0.42       | 0.19 | 0.030  |

**Table S9.4 Average marginal effects of vaccine coverage on mobility, broken down by country socioeconomic development status (continued)**

| Y: daily mobility change (%)              | Retail and recreation |           |               | Grocery and pharmacy |           |               | Transit stations |           |               | Workplaces   |           |               |
|---|-----------------------|-----------|---------------|----------------------|-----------|---------------|------------------|-----------|---------------|--------------|-----------|---------------|
|   | dy/dx                 | SE        | P>z           | dy/dx                | SE        | P>z           | dy/dx            | SE        | P>z           | dy/dx        | SE        | P>z           |
| No. of people vaccinated (per ten people) |                       |           |               |                      |           |               |                  |           |               |              |           |               |
| at:                                       |                       |           |               |                      |           |               |                  |           |               |              |           |               |
| Employment in industry = 14.23 (p10)      | 4.31                  | 0.43      | <0.001        | 4.94                 | 0.55      | <0.001        | 3.15             | 0.52      | <0.001        | 1.79         | 0.26      | <0.001        |
| Employment in industry = 18.81 (p30)      | 3.96                  | 0.33      | <0.001        | 4.61                 | 0.42      | <0.001        | 2.94             | 0.38      | <0.001        | 1.58         | 0.20      | <0.001        |
| Employment in industry = 20.82 (p50)      | 3.80                  | 0.29      | <0.001        | 4.47                 | 0.37      | <0.001        | 2.85             | 0.33      | <0.001        | 1.48         | 0.18      | <0.001        |
| Employment in industry = 24.85 (p70)      | 3.48                  | 0.22      | <0.001        | 4.17                 | 0.30      | <0.001        | 2.67             | 0.25      | <0.001        | 1.29         | 0.15      | <0.001        |
| Employment in industry = 30.11 (p90)      | 3.07                  | 0.21      | <0.001        | 3.79                 | 0.30      | <0.001        | 2.44             | 0.24      | <0.001        | 1.05         | 0.17      | <0.001        |
|   | <u>dy/dx</u>          | <u>SE</u> | <u>P&gt;z</u> | <u>dy/dx</u>         | <u>SE</u> | <u>P&gt;z</u> | <u>dy/dx</u>     | <u>SE</u> | <u>P&gt;z</u> | <u>dy/dx</u> | <u>SE</u> | <u>P&gt;z</u> |
| No. of people vaccinated (per ten people) |                       |           |               |                      |           |               |                  |           |               |              |           |               |
| at:                                       |                       |           |               |                      |           |               |                  |           |               |              |           |               |
| Employment in service = 42.11 (p10)       | 5.71                  | 0.75      | <0.001        | 7.73                 | 1.21      | <0.001        | 4.80             | 0.85      | <0.001        | 2.42         | 0.52      | <0.001        |
| Employment in service = 56.14 (p30)       | 4.53                  | 0.43      | <0.001        | 5.79                 | 0.67      | <0.001        | 3.64             | 0.48      | <0.001        | 1.84         | 0.30      | <0.001        |
| Employment in service = 63.39 (p50)       | 3.93                  | 0.29      | <0.001        | 4.79                 | 0.42      | <0.001        | 3.04             | 0.33      | <0.001        | 1.54         | 0.20      | <0.001        |
| Employment in service = 71.08 (p70)       | 3.28                  | 0.22      | <0.001        | 3.73                 | 0.26      | <0.001        | 2.41             | 0.27      | <0.001        | 1.23         | 0.15      | <0.001        |
| Employment in service = 78.90 (p90)       | 2.62                  | 0.30      | <0.001        | 2.64                 | 0.39      | <0.001        | 1.76             | 0.38      | <0.001        | 0.90         | 0.21      | <0.001        |
|   | <u>dy/dx</u>          | <u>SE</u> | <u>P&gt;z</u> | <u>dy/dx</u>         | <u>SE</u> | <u>P&gt;z</u> | <u>dy/dx</u>     | <u>SE</u> | <u>P&gt;z</u> | <u>dy/dx</u> | <u>SE</u> | <u>P&gt;z</u> |
| No. of people vaccinated (per ten people) |                       |           |               |                      |           |               |                  |           |               |              |           |               |
| at:                                       |                       |           |               |                      |           |               |                  |           |               |              |           |               |
| Employment in agriculture = 1.37 (p10)    | 2.54                  | 0.26      | <0.001        | 2.67                 | 0.33      | <0.001        | 1.77             | 0.32      | <0.001        | 0.84         | 0.18      | <0.001        |
| Employment in agriculture = 3.76 (p30)    | 2.83                  | 0.23      | <0.001        | 3.11                 | 0.27      | <0.001        | 2.03             | 0.28      | <0.001        | 0.99         | 0.16      | <0.001        |
| Employment in agriculture = 9.62 (p50)    | 3.55                  | 0.22      | <0.001        | 4.18                 | 0.29      | <0.001        | 2.68             | 0.27      | <0.001        | 1.36         | 0.16      | <0.001        |
| Employment in agriculture = 21.66 (p70)   | 5.02                  | 0.46      | <0.001        | 6.38                 | 0.73      | <0.001        | 4.00             | 0.56      | <0.001        | 2.12         | 0.35      | <0.001        |
| Employment in agriculture = 38.7 (p90)    | 7.09                  | 0.92      | <0.001        | 9.49                 | 1.47      | <0.001        | 5.87             | 1.10      | <0.001        | 3.19         | 0.70      | <0.001        |

**Table S9.4 Average marginal effects of vaccine coverage on mobility, broken down by country socioeconomic development status (continued)**

| Y: daily mobility change (%)                 | Retail and recreation |      |        | Grocery and pharmacy |      |        | Transit stations |      |        | Workplaces |      |        |
|--|-----------------------|------|--------|----------------------|------|--------|------------------|------|--------|------------|------|--------|
|  | dy/dx                 | SE   | P>z    | dy/dx                | SE   | P>z    | dy/dx            | SE   | P>z    | dy/dx      | SE   | P>z    |
| No. of people vaccinated (per ten people)    |                       |      |        |                      |      |        |                  |      |        |            |      |        |
| at:  |                       |      |        |                      |      |        |                  |      |        |            |      |        |
| Self-employment = 8.45 (p10)                 | 2.19                  | 0.28 | <0.001 | 2.23                 | 0.38 | <0.001 | 1.47             | 0.34 | <0.001 | 0.62       | 0.19 | 0.001  |
| Self-employment = 15.03 (p30)                | 2.81                  | 0.23 | <0.001 | 3.12                 | 0.29 | <0.001 | 2.02             | 0.27 | <0.001 | 0.96       | 0.15 | <0.001 |
| Self-employment = 25.05 (p50)                | 3.74                  | 0.22 | <0.001 | 4.47                 | 0.31 | <0.001 | 2.85             | 0.28 | <0.001 | 1.46       | 0.16 | <0.001 |
| Self-employment = 39.34 (p70)                | 5.08                  | 0.37 | <0.001 | 6.40                 | 0.57 | <0.001 | 4.08             | 0.48 | <0.001 | 2.19       | 0.29 | <0.001 |
| Self-employment = 64.37 (p90)                | 7.42                  | 0.74 | <0.001 | 9.78                 | 1.15 | <0.001 | 6.13             | 0.95 | <0.001 | 3.45       | 0.57 | <0.001 |
|  | dy/dx                 | SE   | P>z    | dy/dx                | SE   | P>z    | dy/dx            | SE   | P>z    | dy/dx      | SE   | P>z    |
| No. of people vaccinated (per ten people)    |                       |      |        |                      |      |        |                  |      |        |            |      |        |
| at:  |                       |      |        |                      |      |        |                  |      |        |            |      |        |
| Individuals using the internet = 31.9 (p10)  | 8.26                  | 0.82 | <0.001 | 11.36                | 1.25 | <0.001 | 7.13             | 1.02 | <0.001 | 3.87       | 0.63 | <0.001 |
| Individuals using the internet = 59.6 (p30)  | 5.44                  | 0.40 | <0.001 | 7.07                 | 0.60 | <0.001 | 4.50             | 0.50 | <0.001 | 2.38       | 0.31 | <0.001 |
| Individuals using the internet = 73.48 (p50) | 4.03                  | 0.24 | <0.001 | 4.92                 | 0.32 | <0.001 | 3.17             | 0.30 | <0.001 | 1.63       | 0.18 | <0.001 |
| Individuals using the internet = 83.00 (p70) | 3.06                  | 0.21 | <0.001 | 3.44                 | 0.25 | <0.001 | 2.27             | 0.26 | <0.001 | 1.12       | 0.15 | <0.001 |
| Individuals using the internet = 91.80 (p90) | 2.16                  | 0.27 | <0.001 | 2.08                 | 0.34 | <0.001 | 1.43             | 0.33 | <0.001 | 0.65       | 0.19 | 0.001  |

Note: Random-effects models were applied. The marginal effect was noted by dy/dx, and estimated from coefficients presented in Table S8.2. Standard errors were clustered at the country level and estimated by using the Delta-method.

