**Table of Contents**

[Supplementary methods 2](#_Toc81833737)

[Figure S1: Countries included in this study. 4](#_Toc81833738)

[Figure S2: SHAP main effect value of each NPI at different intensity levels. 5](#_Toc81833739)

[Figure S3: The time need to take effect for each NPI 8](#_Toc81833740)

[Figure S4: Interaction between each pair of NPIs. 9](#_Toc81833741)

[Figure S5: SHAP interaction value of each pair of NPIs 10](#_Toc81833742)

[Table S1 The description of each NPI 12](#_Toc81833743)

[Table S2 Results of sensitivity analysis 16](#_Toc81833744)

[References 17](#_Toc81833745)

# Supplementary methods

Specifically, each intensity level of an NPI has a SHAP value, which was calculated conditioning on all possible NPI orderings. The size of the SHAP value of a NPI at an intensity level represents the change of predicted value caused by this NPI at this intensity level. The model predicted value was calculated using the following formula:

in which stands for the number of features, and stands for mean predicted value.

The model predicted value could be approximated to the sum of the SHAP value of each feature adding the mean predicted value. Each NPI’s contribution in suppressing the influenza transmission at 2019-2020 influenza season was calculated by the sum of positive SHAP values.

The SHAP main effect value of each NPI at each intensity level was calculated by the difference between the SHAP value and the sum of each SHAP interaction value according to the following formula.

which stands for other NPIs interacted with NPI .

The statistical significance of the effectiveness (SHAP main effect value) of each NPI at different intensity levels in suppressing influenza transmission were tested by one-sided one-sample t-test if the sample size was above 30 or data follow the normal distribution, otherwise the nonparametric Wilcoxon test would be used. The average values of those NPI intensity levels with p < 0.05 were ranked, and then grouped the NPI intensity levels into “strong”, “moderate”, and “weak” by using K-means clustering.

Given that many governments rolled out several NPIs simultaneously, The interaction effect among all pairs of NPIs at each intensity level were assessed using SHAP interaction value. The positive interaction effect is an additional effect of the combination of two NPIs at specific intensity levels on suppression of influenza transmission, whereas the negative interaction is a reduced effect on suppression of influenza transmission. All intensity levels of each NPI were divided into two groups (effective vs ineffective) based on the results of SHAP main effect value. In each of the two groups, the SHAP interaction values at different levels were averaged as group SHAP interaction values. For each pair of NPIs, the overall SHAP interaction value was calculated by taking the sum of the four absolute group SHAP interaction values. The two pairs of NPIs with the largest overall SHAP interaction effect were further explored.



Figure S1: Countries included in this study. (Including Austria, Belgium, Bulgaria, Canada, China, Denmark, France, Georgia, Germany, Greece, Hungary, Iceland, Iran (Islamic Republic of), Ireland, Israel, Italy, Kazakhstan, Latvia, Lithuania, Mongolia, Norway, Poland, Portugal, Republic of Moldova, Romania, Russian Federation, Serbia, Slovenia, Spain, Sweden, Ukraine, United Kingdom of Great Britain and Northern Ireland, and United States of America)



Figure S2: SHAP main effect value of each NPI at different intensity levels. For each NPI, the first time that its SHAP main effect value exceeded zero represents that the NPI with the corresponding intensity level started to suppress influenza transmission, and the intensity below this level means that the NPI did not produce effect. The inflection point in the plot corresponds to the intensity of the NPI that could approximately reach the maximal effect.



# Figure S3: The time need to take effect for each NPI



Figure S4: Interaction between each pair of NPIs. (A) Positive interaction; (B) Negative interaction; The plus sign () after the name of NPI denotes that this NPI exceeds its minimal intensity to take effect; The minus sign () after the name of NPI denotes that this NPI is below its minimal intensity to take effect; The width of the band between each pair of NPIs denotes the size of SHAP interaction value. Different colors represent different NPIs.



# Figure S5: SHAP interaction value of pair of NPIs

Table S1 The description of each NPI1

|  |  |  |  |
| --- | --- | --- | --- |
| NPI | Implementation level and corresponding description | Implementation scopea | Intensity value |
| School closure | (0) no measures |  | 0 |
| (1) recommend closing or all schools open with alterations resulting in significant differences compared to non-Covid-19 operations | 0 | 17 |
| 1 | 33 |
| (2) require closing (only some levels or categories, e.g., just high school, or just public schools) | 0 | 50 |
| 1 | 67 |
| (3) require closing all levels | 0 | 83 |
| 1 | 100 |
| Workplace closure | (0) no measures |  | 0 |
| (1) recommend closing (or recommend work from home) | 0 | 17 |
| 1 | 33 |
| (2) require closing (or work from home) for some sectors or categories of workers | 0 | 50 |
| 1 | 67 |
| (3) require closing (or work from home) for all-but-essential workplaces (e.g., grocery stores, doctors) | 0 | 83 |
| 1 | 100 |
| Public events cancellation | (0) no measures |  | 0 |
| (1) recommend cancelling | 0 | 25 |
| 1 | 50 |
| (2) require cancelling | 0 | 75 |
| 1 | 100 |
| Gathering limitation | (0) no measures |  | 0 |
| (1) restrictions on very large gatherings (the limit is above 1000 people) | 0 | 13 |
| 1 | 25 |
| (2) restrictions on gatherings between 101-1000 people | 0 | 38 |
| 1 | 50 |
| (3) restrictions on gatherings between 11-100 people | 0 | 63 |
| 1 | 75 |
| (4) restrictions on gatherings of 10 people or less | 0 | 88 |
| 1 | 100 |
| Public transport suspension | (0) no measures |  | 0 |
| (1) recommend closing (or significantly reduce volume/route/means of transport available) | 0 | 25 |
| 1 | 50 |
| (2) require closing (or prohibit most citizens from using it) | 0 | 75 |
| 1 | 100 |
| Stay at home requirement | (0) no measures |  | 0 |
| (1) recommend not leaving house | 0 | 17 |
| 1 | 33 |
| (2) require not leaving house with exceptions for daily exercise, grocery shopping, and 'essential' trips | 0 | 50 |
| 1 | 67 |
| (3) require not leaving house with minimal exceptions (e.g., allowed to leave once a week, or only one person can leave at a time, etc.) | 0 | 83 |
| 1 | 100 |
| Domestic travel restriction | (0) no measures |  | 0 |
| (1) recommend not to travel between regions/cities | 0 | 25 |
| 1 | 50 |
| (2) internal movement restrictions in place | 0 | 75 |
| 1 | 100 |
| International travel restriction | (0) no measures |  | 0 |
| (1) screening arrivals |  | 25 |
| (2) quarantine arrivals from some or all regions |  | 50 |
| (3) ban arrivals from some regions |  | 75 |
| (4) ban on all regions or total border closure |  | 100 |
| Unemployment subsidy | (0) no measures |  | 0 |
| (1) government is replacing less than 50% of lost salary (or if a flat sum, it is less than 50% median salary) | 0 | 25 |
| 1 | 50 |
| (2) government is replacing 50% or more of lost salary (or if a flat sum, it is greater than 50% median salary) | 0 | 75 |
| 1 | 100 |
| Debt/contract relief | (0) no measures |  | 0 |
| (1) narrow relief, specific to one kind of contract |  | 50 |
| (2) broad debt/contract relief |  | 100 |
| Health education promotion | (0) no measures |  | 0 |
| (1) public officials urging caution about Covid-19 | 0 | 25 |
| 1 | 50 |
| (2) coordinated public information campaign (e.g., across traditional and social media) | 0 | 75 |
| 1 | 100 |
| Testing policy | (0) no measures |  | 0 |
| (1) only those who both (a) have symptoms AND (b) meet specific criteria (e.g., key workers, admitted to hospital, came into contact with a known case, returned from overseas) |  | 33 |
| (2) testing of anyone showing Covid-19 symptoms |  | 67 |
| (3) open public testing (e.g., "drive through" testing available to asymptomatic people) |  | 100 |
| Contact tracing | (0) no measures |  | 0 |
| (1) limited contact tracing; not done for all cases |  | 50 |
| (2) comprehensive contact tracing; done for all identified cases |  | 100 |
| Mask wearing requirement | (0) no measures |  | 0 |
| (1) Recommended | 0 | 13 |
| 1 | 25 |
| (2) Required in some specified shared/public spaces outside the home with other people present, or some situations when social distancing not possible | 0 | 38 |
| 1 | 50 |
| (3) Required in all shared/public spaces outside the home with other people present or all situations when social distancing not possible | 0 | 63 |
| 1 | 75 |
| (4) Required outside the home at all times regardless of location or presence of other people | 0 | 88 |
| 1 | 100 |

a: 0=Implemented in target regions; 1=Implemented nationwide

# Table S2 Results of sensitivity analysis

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Exclude 1 | Exclude 2 | Unnormalized | No target | RF+SHAP | Lasso | SVR+SFS | RF+SFS |
| Gathering limitation |  |  |  |  |  |  |  |  |
| School closure |  |  |  |  |  |  |  |  |
| Contact tracing |  |  |  |  |  |  |  |  |
| Health education promotion |  |  |  |  |  |  |  |  |
| Mask wearing requirement |  |  |  |  |  |  |  |  |
| Workplace closure |  |  |  |  |  |  |  |  |
| International travel restriction |  |  |  |  |  |  |  |  |
| Debt/contract relief |  |  |  |  |  |  |  |  |
| Testing policy |  |  |  |  |  |  |  |  |
| Domestic travel restriction |  |  |  |  |  |  |  |  |
| Public events cancellation |  |  |  |  |  |  |  |  |
| Public transport suspension |  |  |  |  |  |  |  |  |
| Stay at home requirement |  |  |  |  |  |  |  |  |
| Unemployment subsidy |  |  |  |  |  |  |  |  |

Exclude1: each country was removed one at a time and the analysis was repeated for a total of 33 times; Exclude2: Canada, China, Russia, and United states were excluded from our main analysis; Unnormalized: unnormalized influenza positive rate was used; No target: intensity value was not taken into account; SFS: sequential feature selection; SVR: support vector machine; RF: random forest.

The order of NPI in first column is determined by the ranking of contribution in the main result, with the largest contribution in the first row.

(1) In Exclude1, the NPIs being selected (The contribution of NPIs >10%) for more than 16 times (>50%) were ticked.

(2) The contribution of NPIs >10% in these methods (Exclude2, Unnormalized, No target, and RF+SHAP) were ticked.

(3) NPIs retained in the final model after feature selection by these methods (Lasso, SVR+SFS, and RF+SFS) were ticked.

# References

1. Hale T, Angrist N, Goldszmidt R, et al. A global panel database of pandemic policies (Oxford COVID-19 Government Response Tracker). *Nat Hum Behav* 2021; 5(4): 529-38.