Influenza's plummeting and future dynamics: the roles of mask wearing, mobility change and SARS-CoV-2 interference

Supplementary Material

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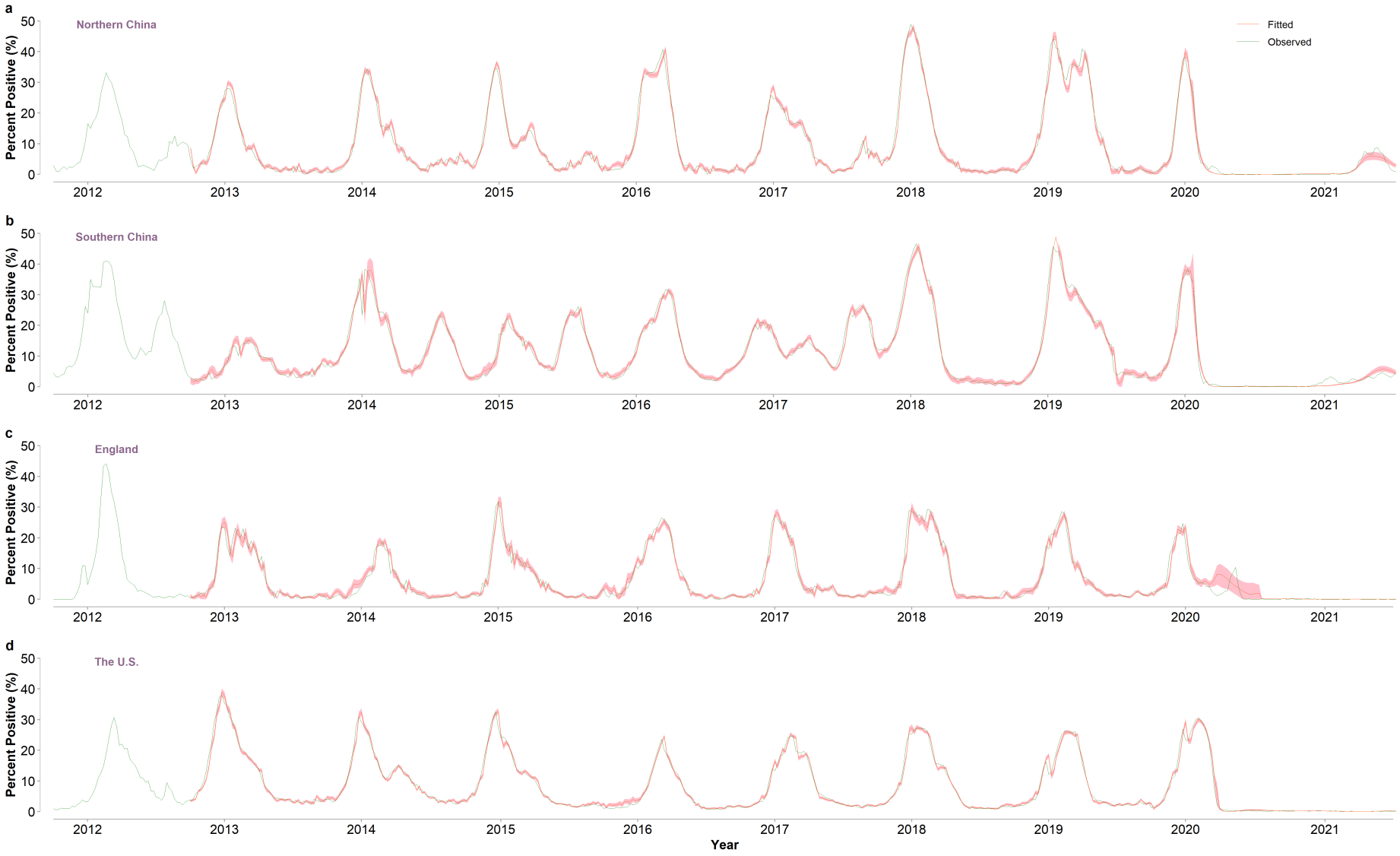
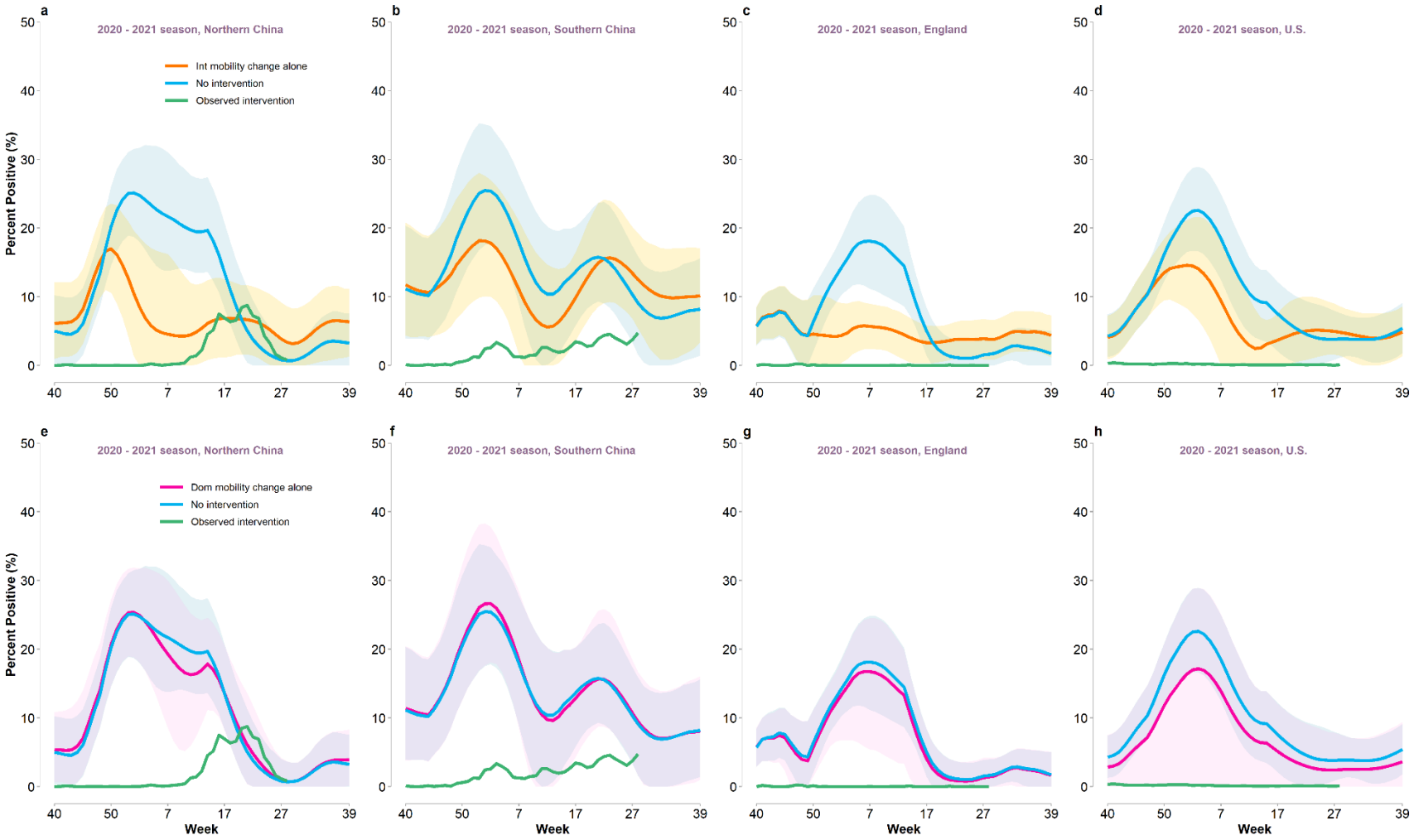
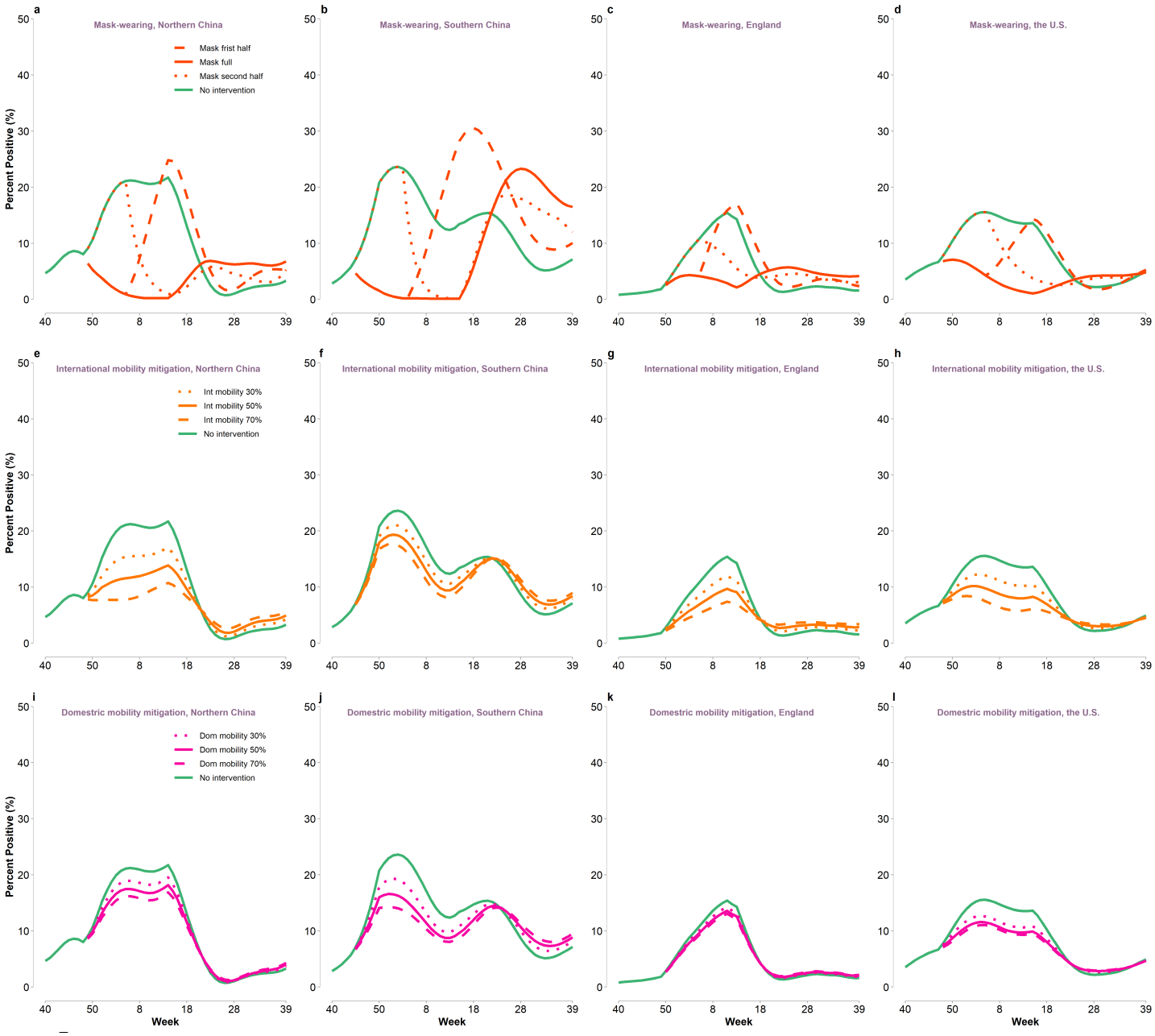


Extended Data Fig. 1 Influenza activity in 2011-2021. a Observed and fitted influenza activities in Northern China. **b** As **a**, but in Southern China. **c** As **a**, but in England. **d** As **a**, but in the U.S..

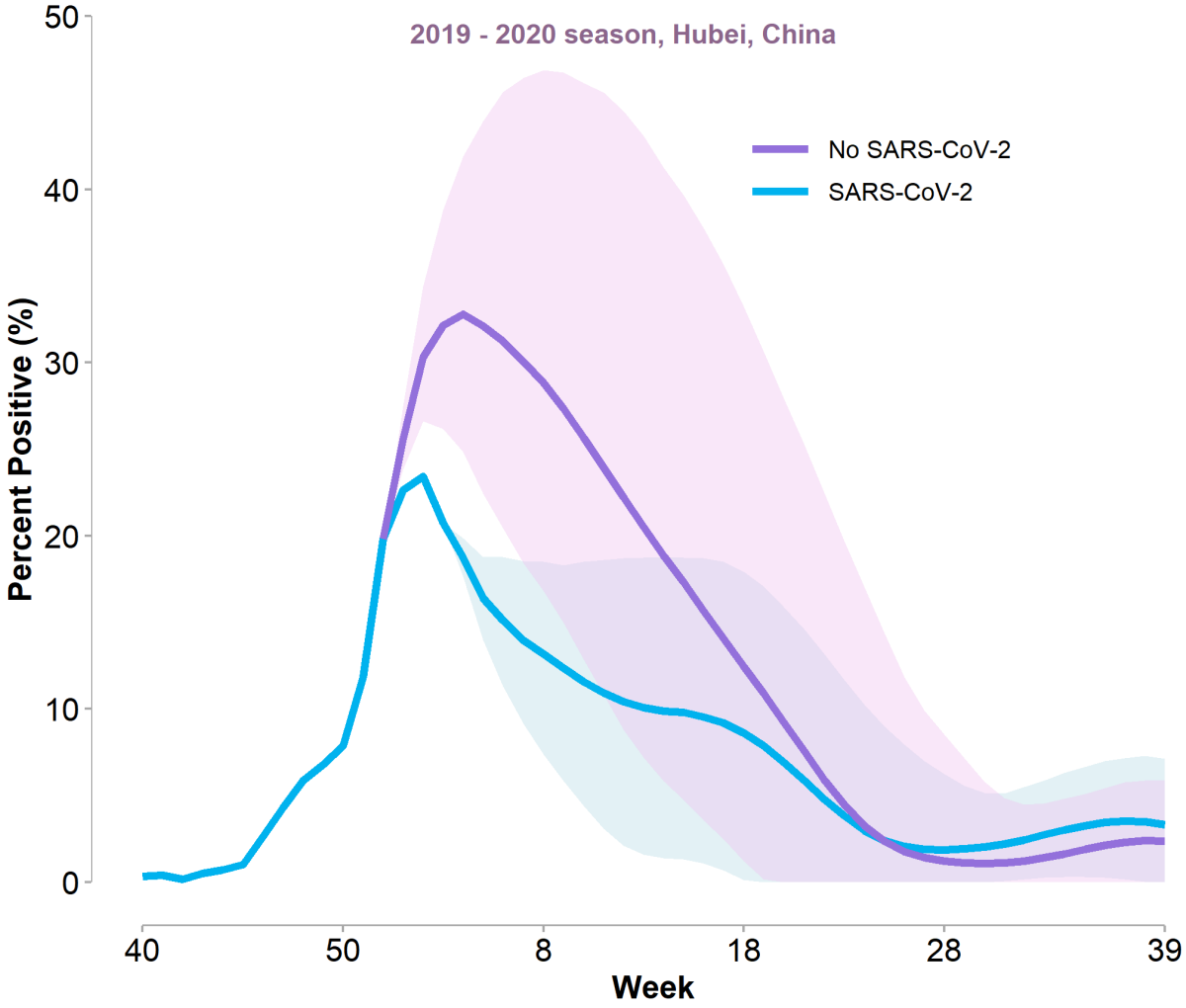


Extended Data Fig. 2 Estimated influenza activities under the international mobility change alone, the domestic mobility change alone and no intervention as well as the observed activity. a Weekly percent positivity in 2019-2020 season for Northern China. **b** As **a**, but for Southern China. **c** As **a**, but for England. **d** As **a**, but for the U.S.. **e** As **a**, but in 2020-2021. **f** As **e**, but for Southern China. **g** As **e**, but for England. **h** As **e**, but for the U.S.. Shaded area refer to 95% CI.

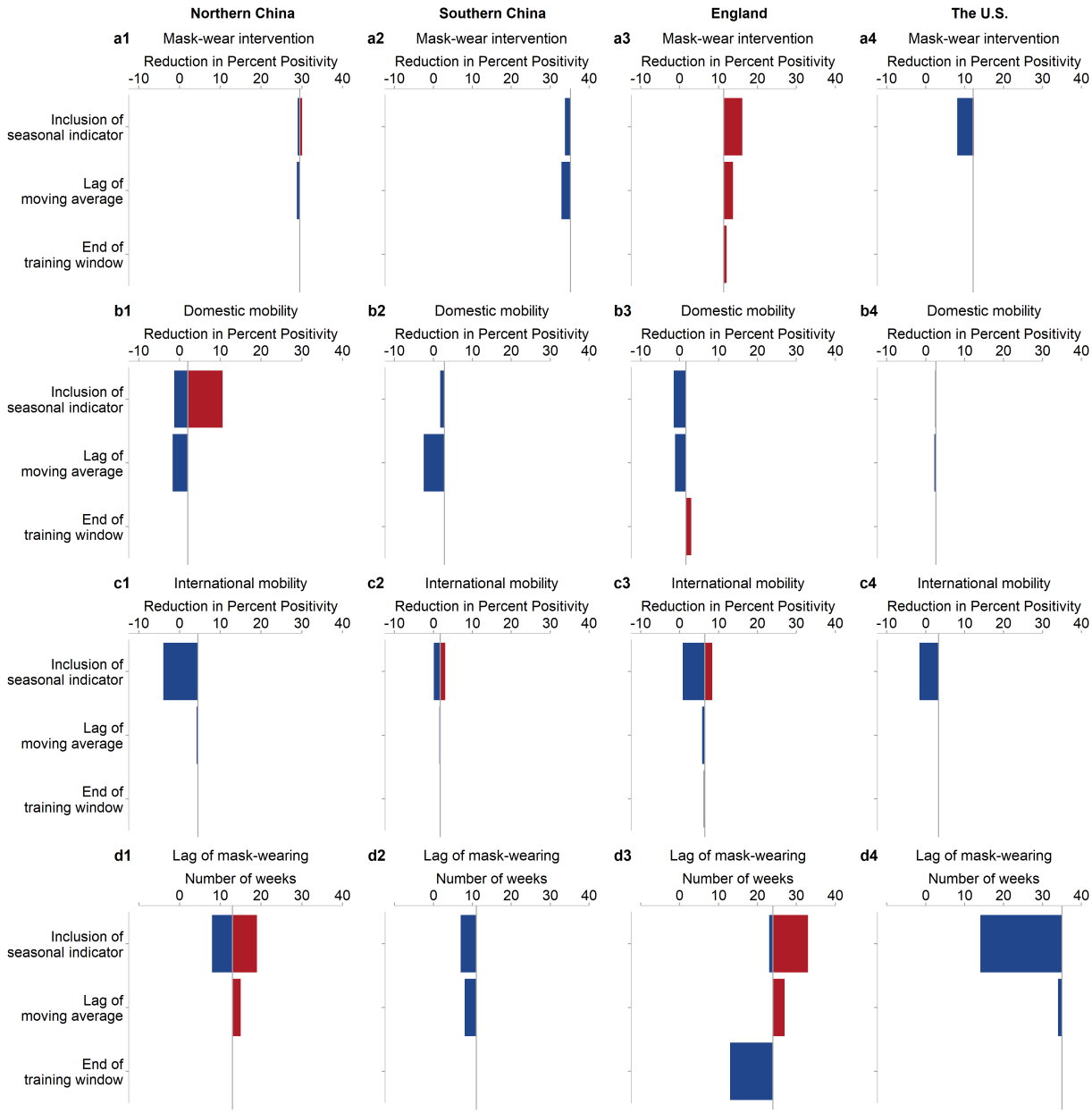


Extended Data Fig. 3 Predicted influenza activities in 2021-2022 season under NPIs with alternative assumptions. a Weekly percent positivity in Northern China under no interventions and three timings of mask-wearing intervention, implemented during the full influenza season, the first half of the season the second half of the season. **b** As **a**, but for Southern China. **c** As **a**, but for England. **d** As **a**, but for U.S. **e** As **a**, but under international mobility mitigation measures, assuming the international mobility reduced by 30%, 50% or 70%. **f** As **e**, but for Southern China. **g** As **e**, but for England. **h** As **e**, but for the U.S.. **i** As **a**, but under domestic mobility mitigation measures, assuming domestic mobility reduced by 30%, 50% or 70%. **j** As **i**, but for Southern China. **k** As **a**, but for England. **l** As **a**, but for the U.S..

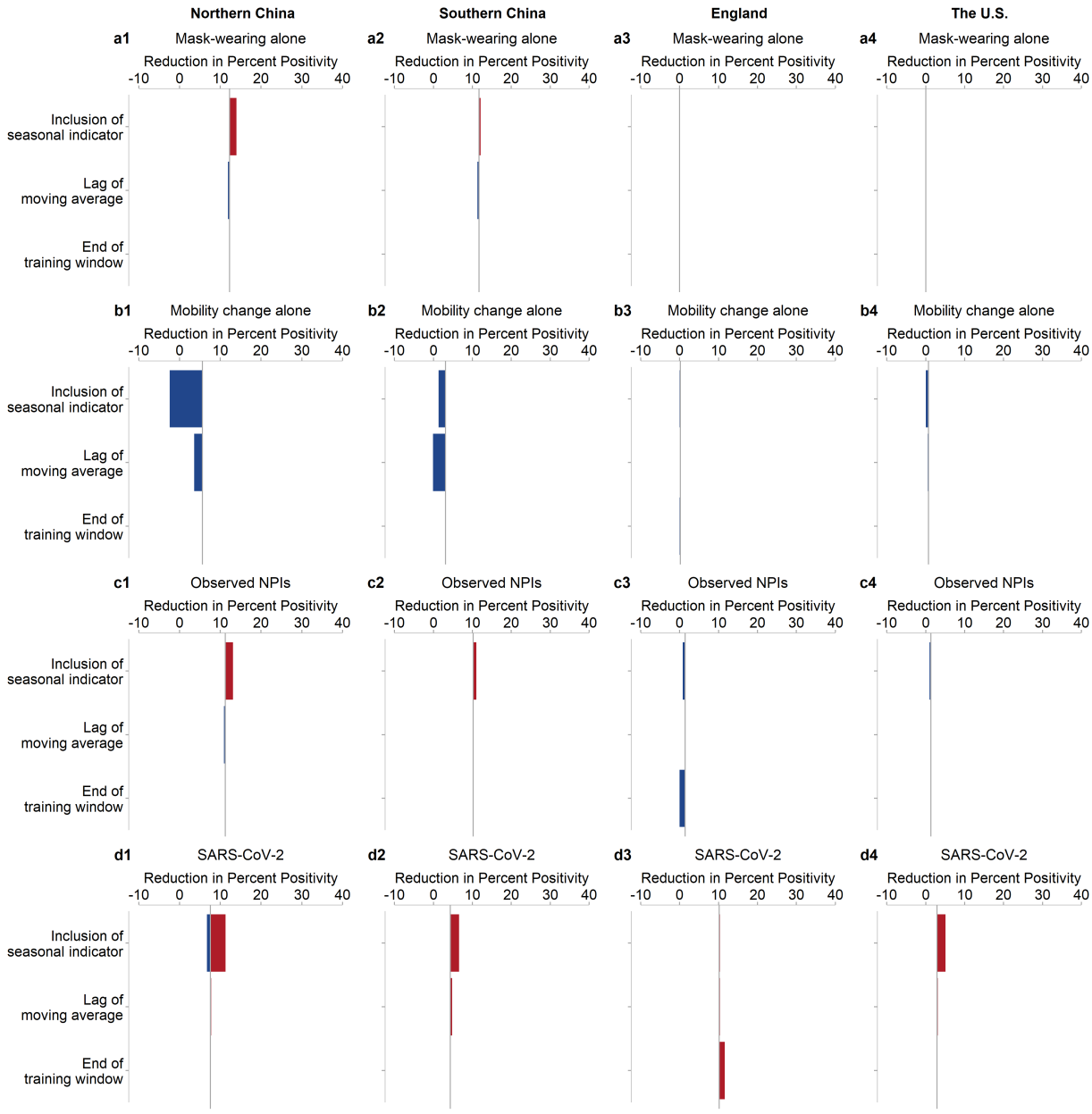
Extended Data Fig. 4 Predicted influenza activities in 2021-2022 season under alternative mask-wearing interventions. a Weekly percent positivity in Northern China under no interventions and three timings of mask-wearing intervention with linger habits of mask use included, implemented during the full influenza season, the first half of the season the second half of the season. **b** As **a**, but for southern China. **c** As **a**, but for England. **d** As **a**, but for the U.S. **e** As **a**, but excluding linger habits of mask use and with mask-wearing intensity 30%, 50% or 70% less than that in baseline. **f** As **e**, but for Southern China. **g** As **e**, but for England. **h** As **e**, but for the U.S.. **i** As **e**, but considering a mask-wearing intervention with intensity 70% less than (i.e., 30% of) that in baseline coordinated with a vaccination program where an extra 20% population vaccinated at 60% vaccine efficacy. **j** As **i**, but for Southern China. **k** As **a**, but for England. **l** As **a**, but for the U.S..



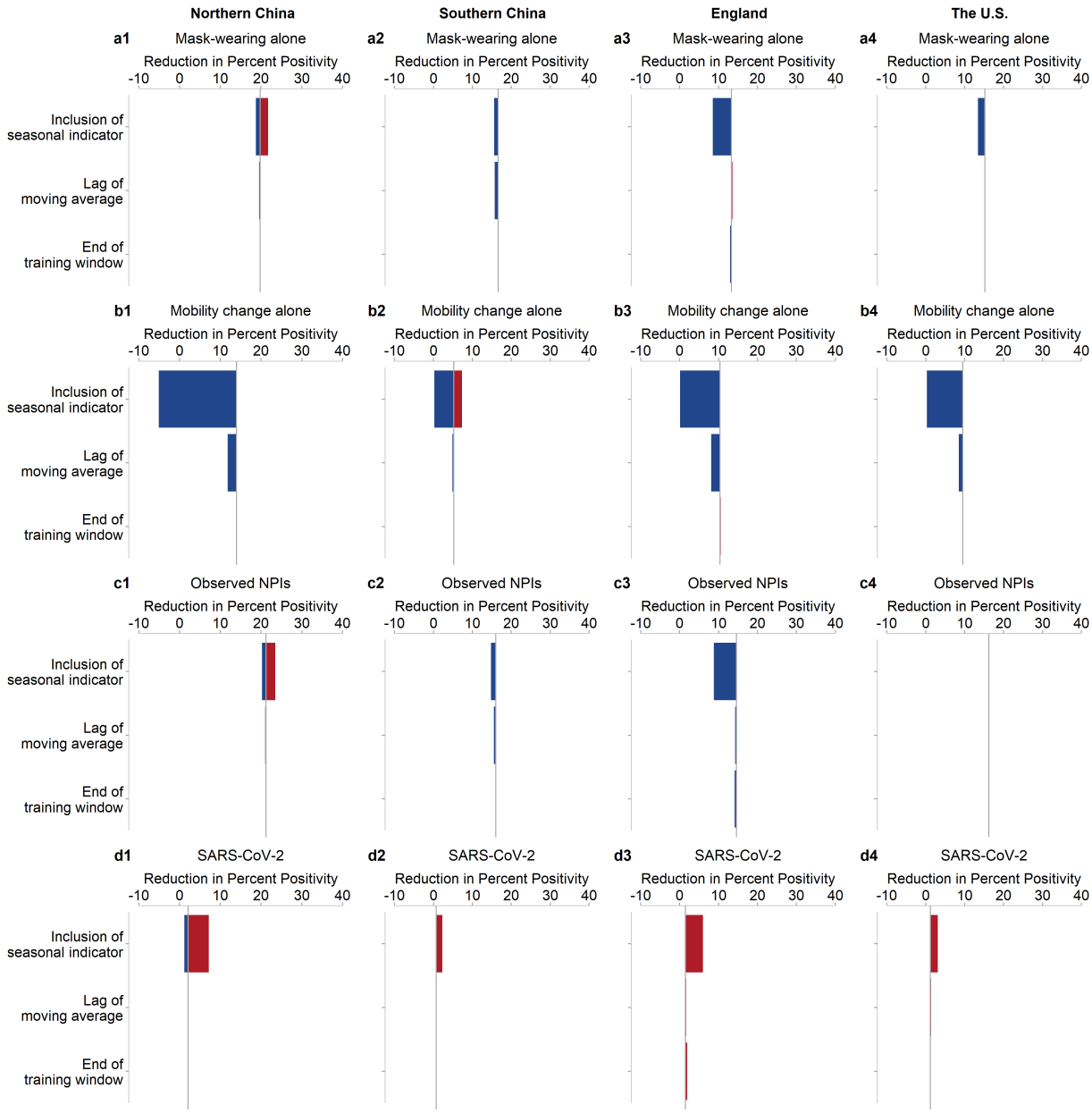
Extended Data Fig. 5 Estimated influenza activities under the scenarios with no SARS-COV-2 transmission and with SARS-COV-2 transmission, both without COVID-19 NPIs in Hubei, China.



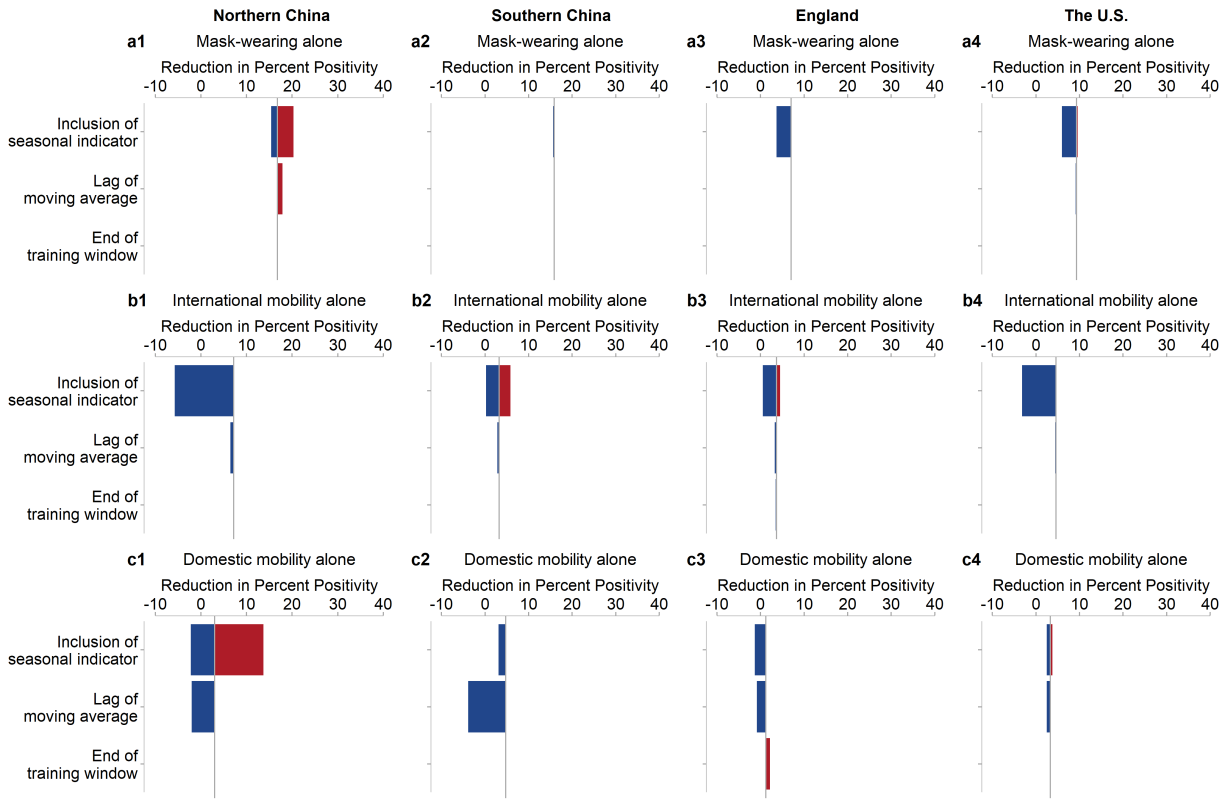
Extended Data Fig. 6 Variations of estimated effects for one-week increase of NPIs and the accumulated time of mask-wearing interventions to achieve the maximal weekly reduction. **a1-a4** Changes of reduction in positive percentage for one-week increase of mask-wearing intervention under different manners in inclusion of the influenza seasonal indicator, different lags used for smoothing the mobility data and an increase of training window until the start of the mask-wearing intervention in Northern China, Southern China, England and the U.S.. **b1-b4** As **a1-a4,** but for domestic mobility mitigation. **c1-c4** As **a1-a4,** but for international mobility mitigation. **d1-d4** As **a1-a4,** but for the lags of mask-wearing intervention included.



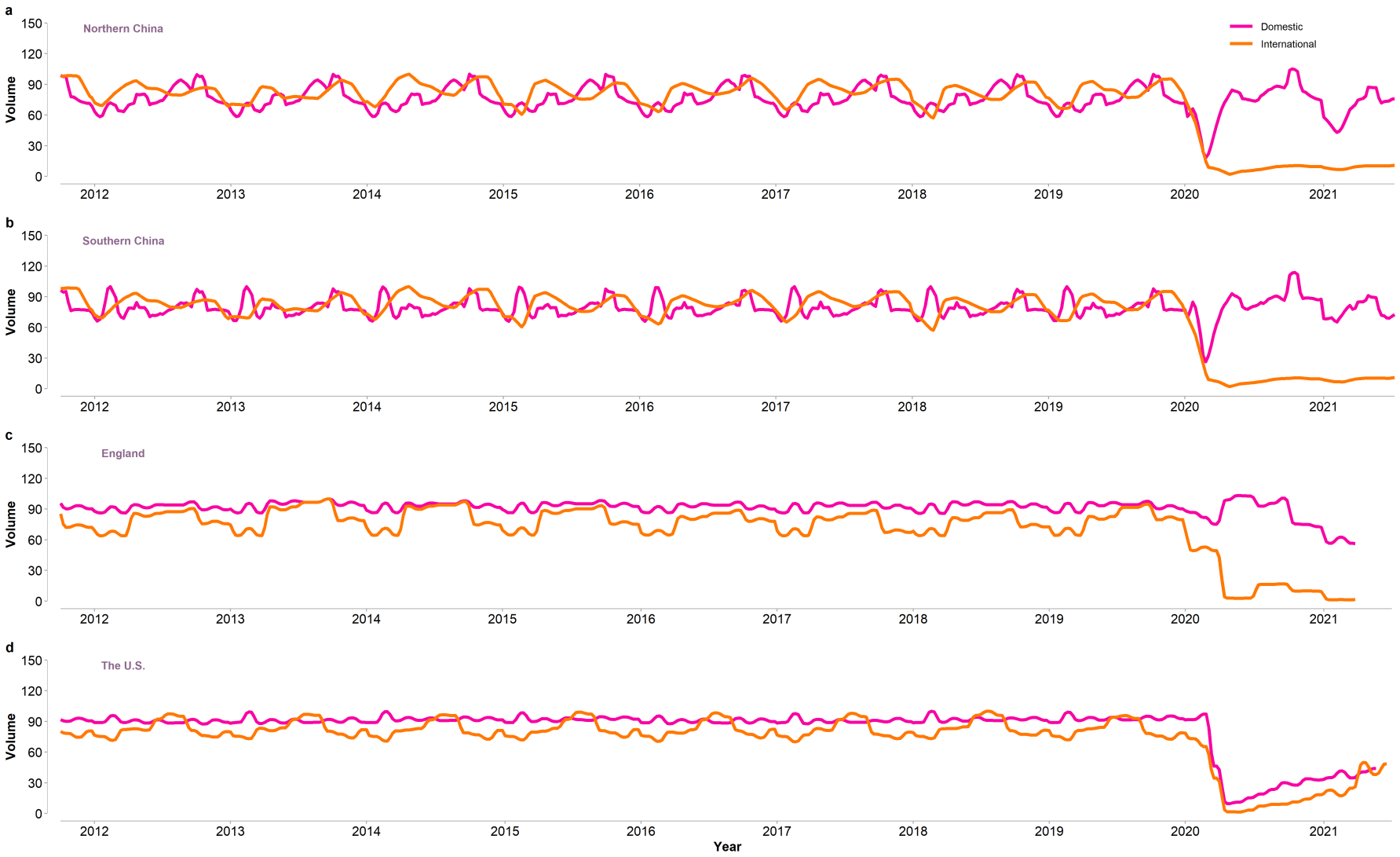
Extended Data Fig. 7 Variations of estimated effects of mask-wearing and mobility mitigation and SARS-CoV-2 interference in the 2019-2020 influenza season. a1-a4 Changes of reduction in percent positive for mask-wearing intervention under different manners in inclusion of the influenza seasonal indicator, different lags used for smoothing the mobility data and an increase of training window until the start of the mask-wearing intervention in Northern China, Southern China, England and the U.S.. **b1-b4** As **a1-a4,** but for domestic mobility mitigation. **c1-c4** As **a1-a4,** but for international mobility mitigation. **d1-d4** As **a1-a4,** but for the SARS-CoV-2 interference.



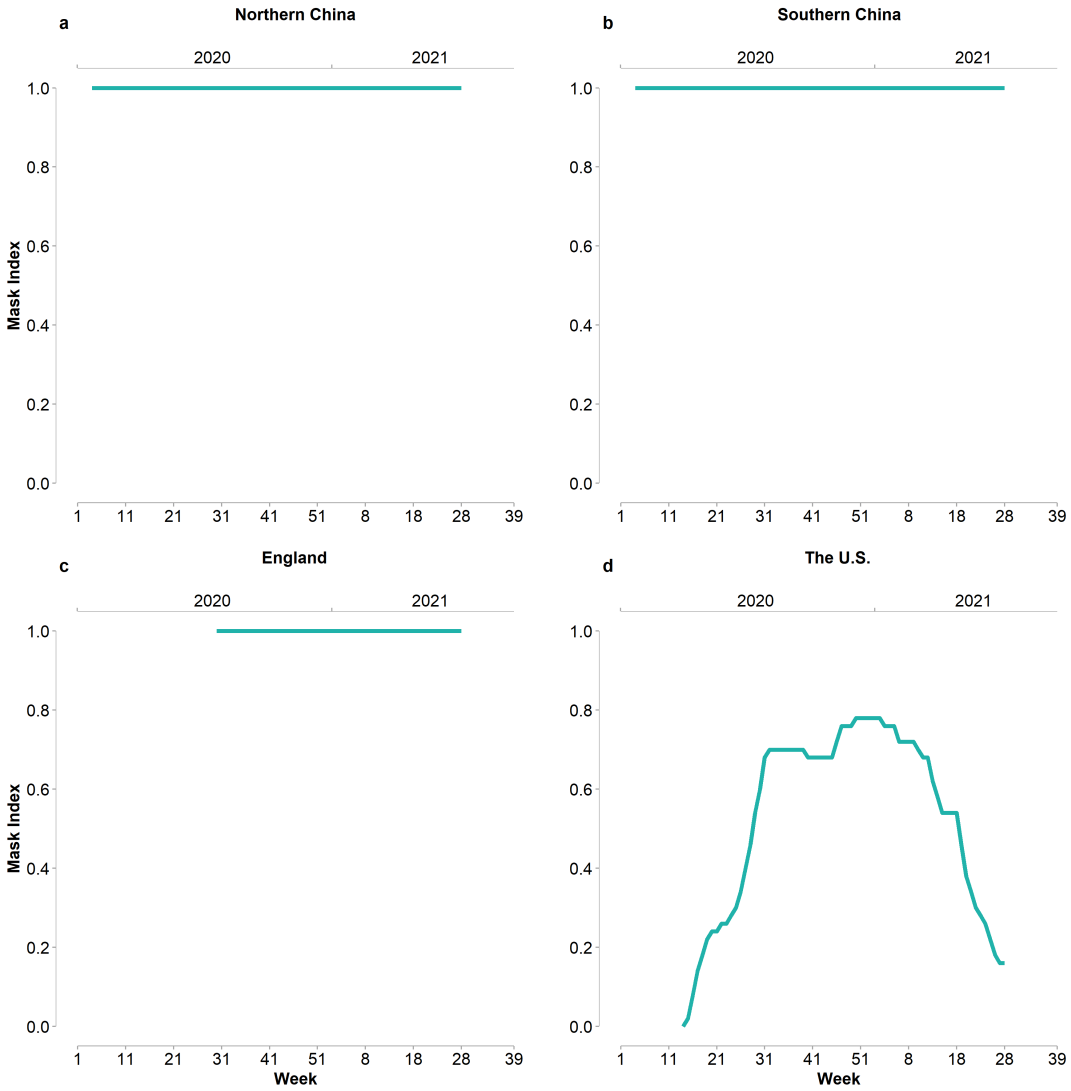
Extended Data Fig. 8 Variations of estimated effects of mask-wearing and mobility mitigation and SARS-CoV-2 interference in the 2020-2021 influenza season. a1-a4 Changes of reduction in percent positive for mask-wearing intervention under different manners in inclusion of the influenza seasonal indicator, different lags used for smoothing the mobility data and an increase of training window until the start of the mask-wearing intervention in Northern China, Southern China, England and the U.S.. **b1-b4** As **a1-a4,** but for domestic mobility mitigation. **c1-c4** As **a1-a4,** but for international mobility mitigation. **d1-d4** As **a1-a4,** but for the SARS-CoV-2 interference.



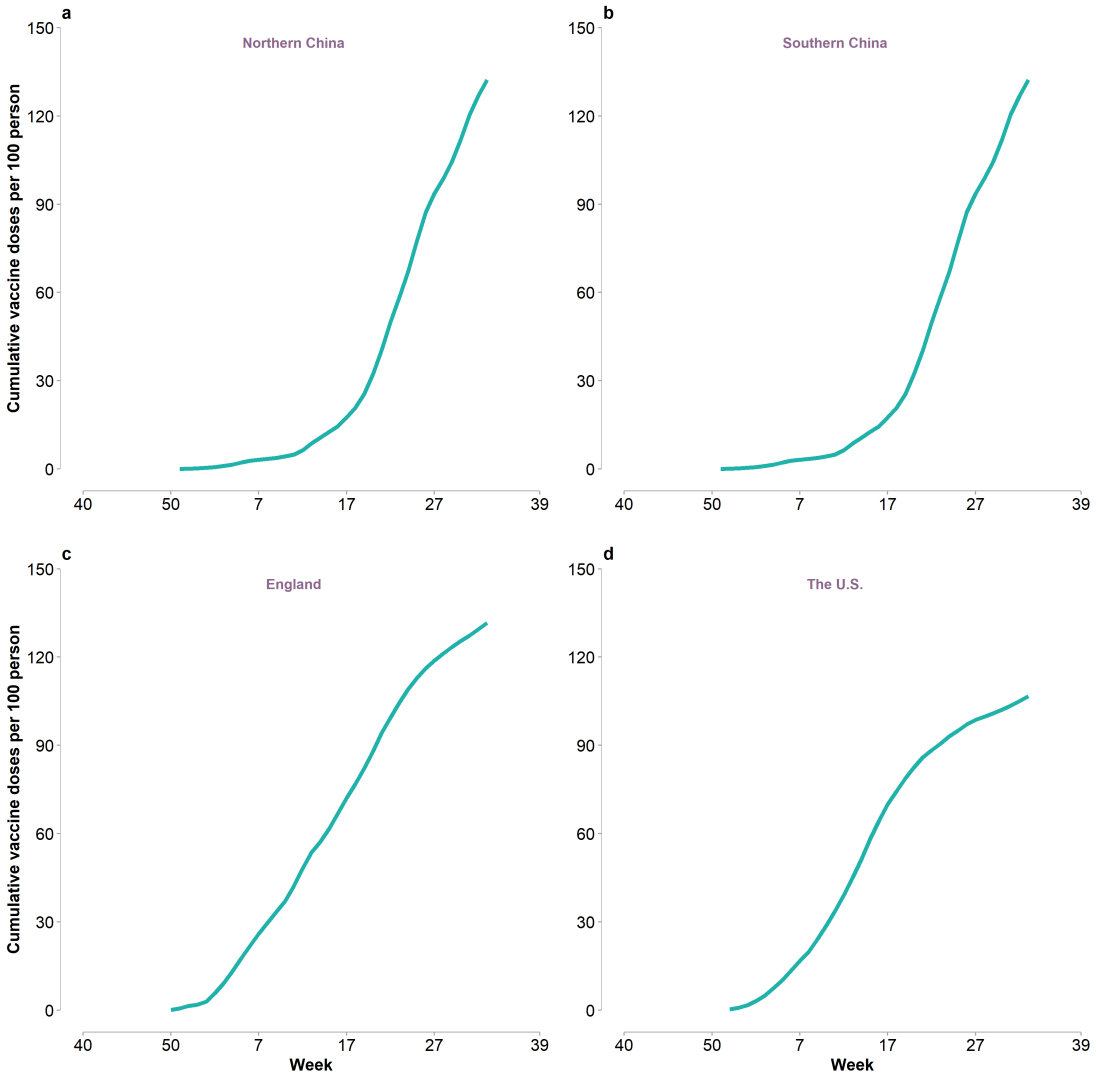
Extended Data Fig. 9 Variations of estimated effects of mask-wearing and mobility mitigation and SARS-CoV-2 interference in the 2021-2022 influenza season. a1-a4 Changes of reduction in percent positive for mask-wearing intervention under different manners in inclusion of the influenza seasonal indicator, different lags used for smoothing the mobility data and an increase of training window until the start of the mask-wearing intervention in Northern China, Southern China, England and the U.S.. **b1-b4** As **a1-a4,** but for domestic mobility mitigation. **c1-c4** As **a1-a4,** but for international mobility mitigation. **d1-d4** As **a1-a4,** but for the SARS-CoV-2 interference.



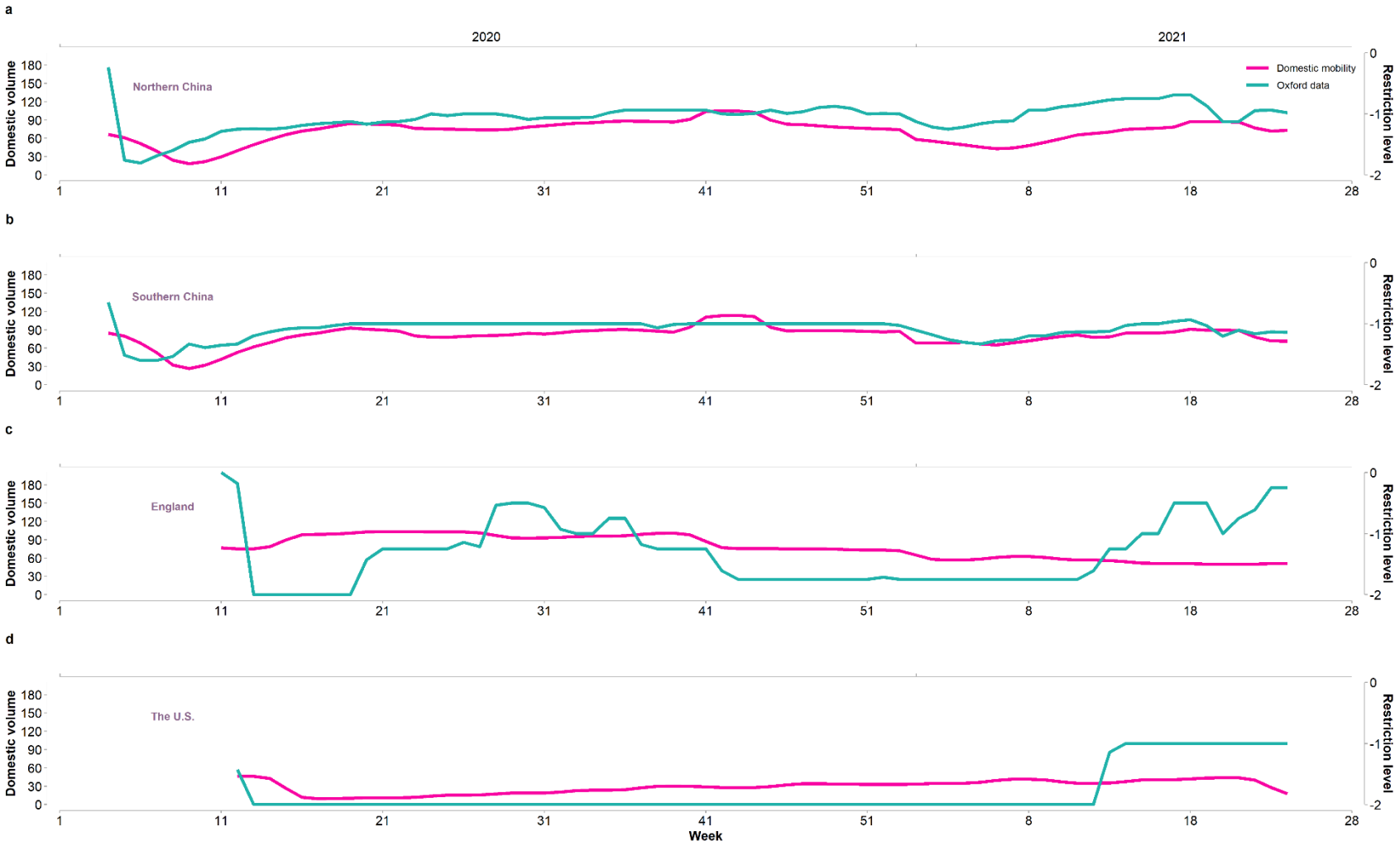
Extended Data Fig. 10 Domestic and international mobility in 2011-2021. a Domestic and international mobility in Northern China. **b** As **a**, but in Southern China. **c** As **a**, but in England. **d** As **a**, but in the U.S..



Extended Data Fig. 11 Mask-wearing intervention during the COVID-19 pandemic. a Mask index in Northern China. **b** As **a**, but in Southern China. **c** As **a**, but in England. **d** As **a**, but in the U.S..

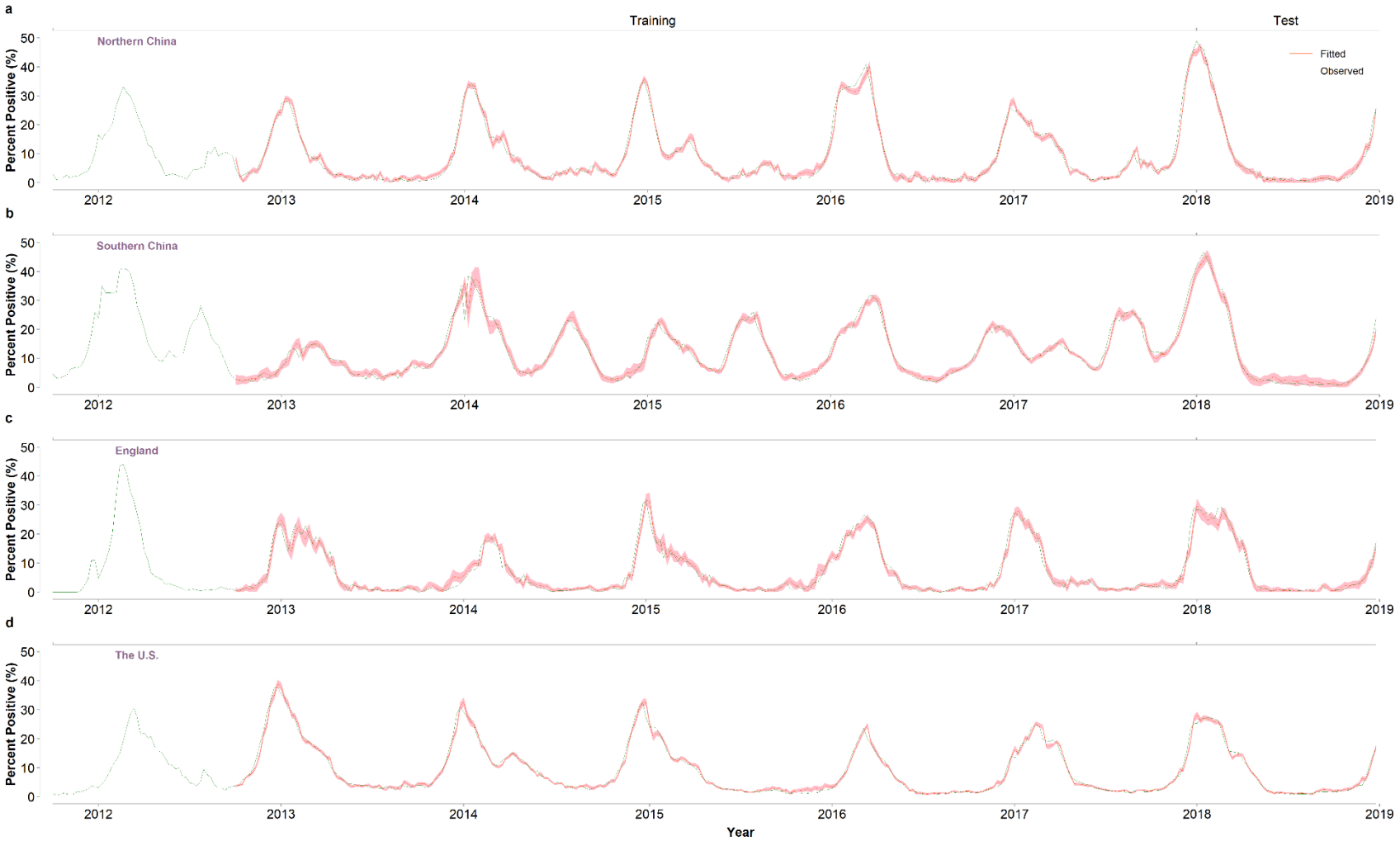


Extended Data Fig. 12 Vaccination coverage during the COVID-19 pandemic in 2020-2021. a Cumulative vaccine doses per 100 persons in Northern China. **b** As **a**, but in Southern China. **c** As **a**, but in England. **d** As **a**, but in the U.S..

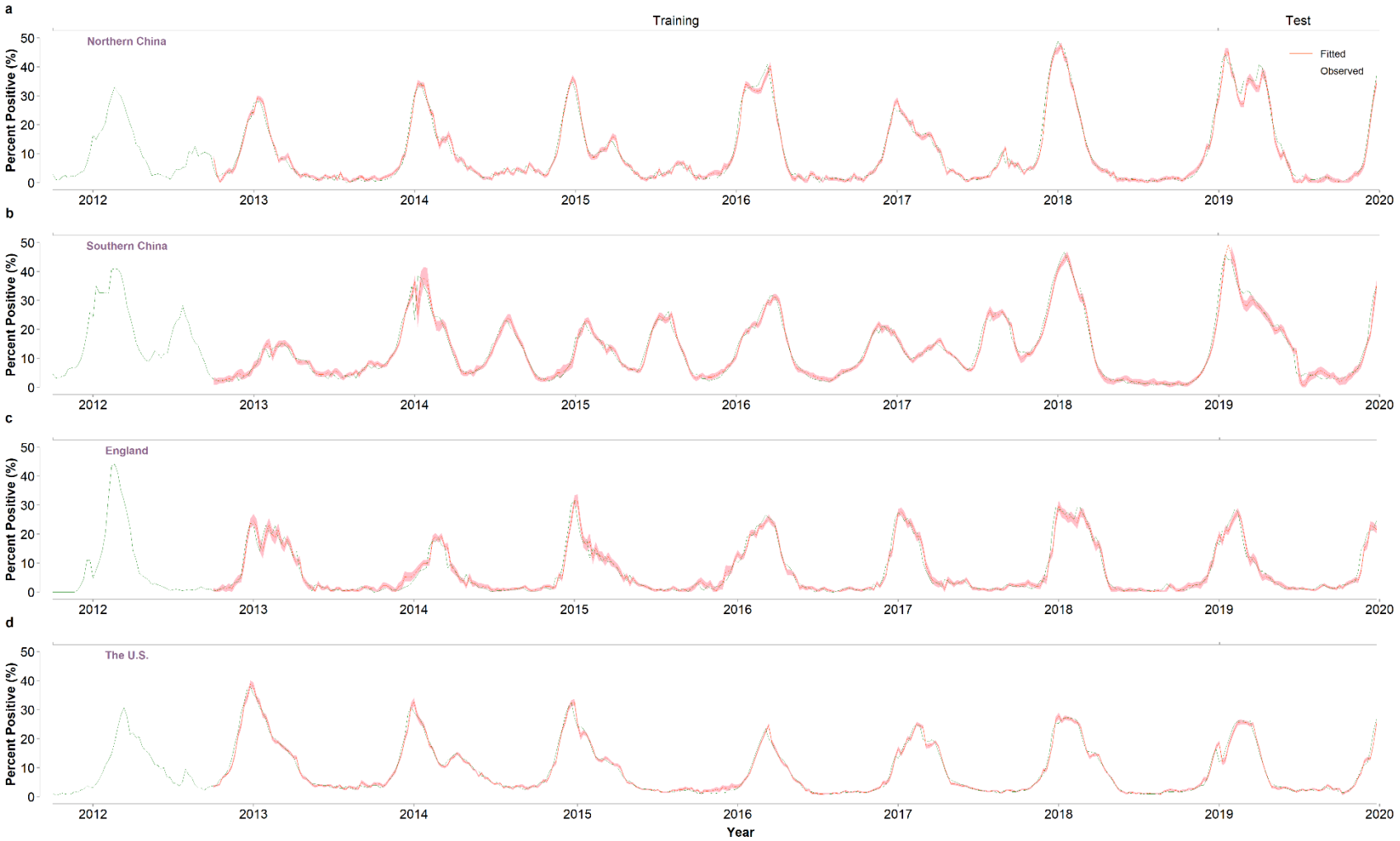


Extended Data Fig. 13 Domestic mobility and restriction level in the COVID-19 period. Restriction levels are estimated using the data from the Oxford COVID-19 Government Response Tracker[1] and were added a negative sign for illustration. Domestic mobility is more variable than the domestic restriction policy but the two are still moderately correlated (Extended Data Table 4).

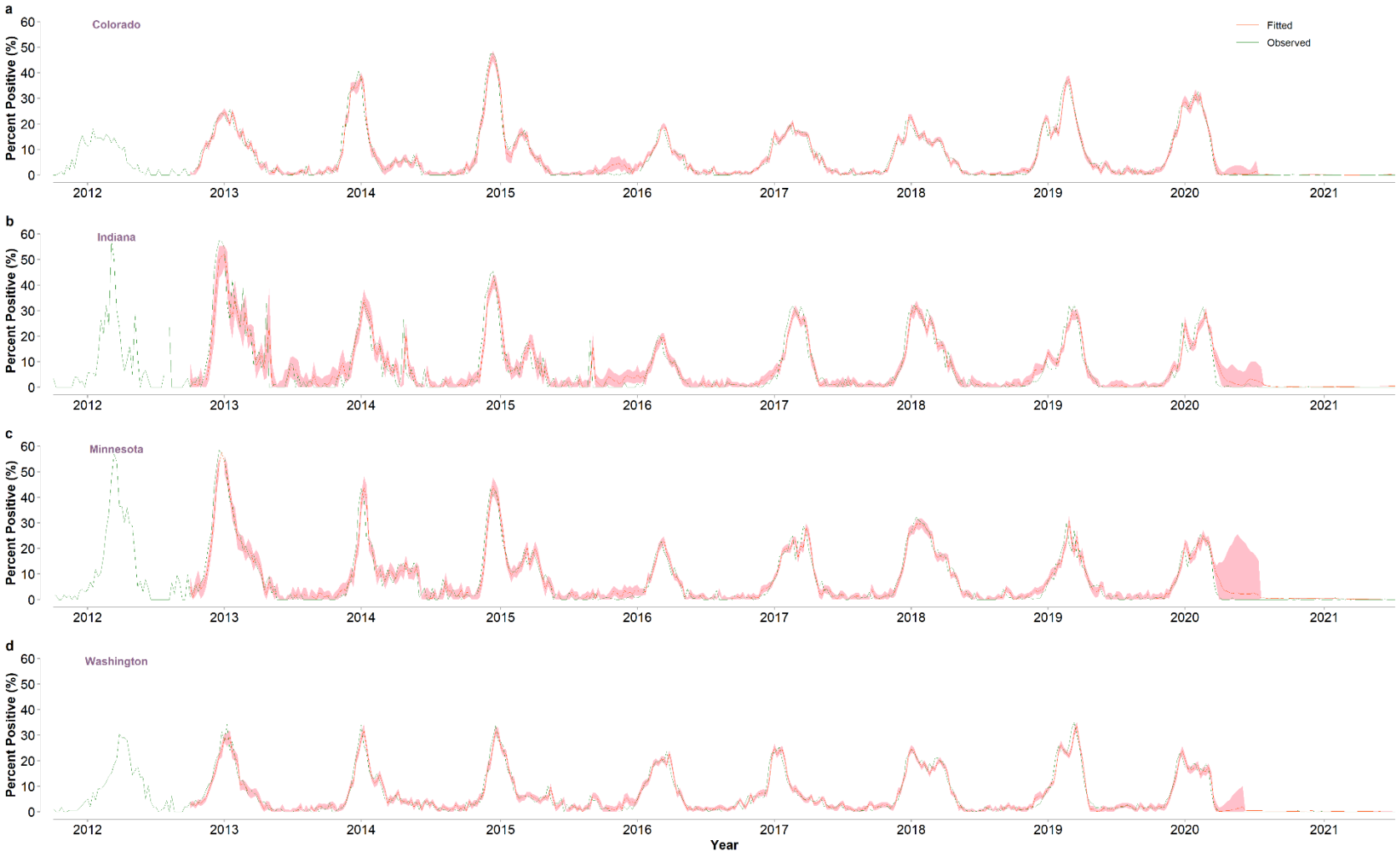
Extended Data Fig. 14 Fitted influenza activity that is obtained from using the 2011-2016 data for training and the 2017 data for test, in comparison to observed influenza activity.



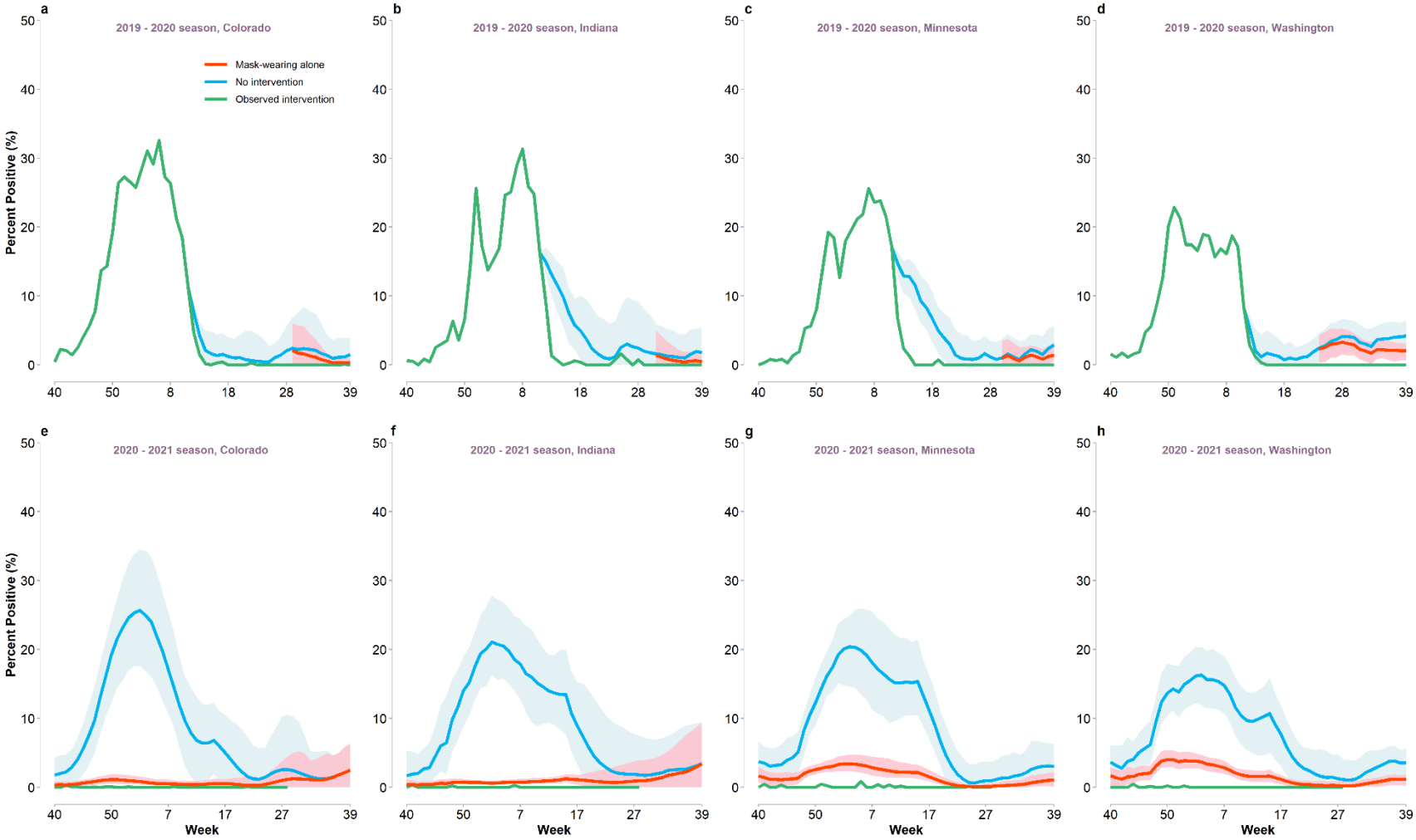
Extended Data Fig. 15 Fitted influenza activity that is obtained from using the 2011-2017 data for training and the 2018 data for test, in comparison to observed influenza activity.



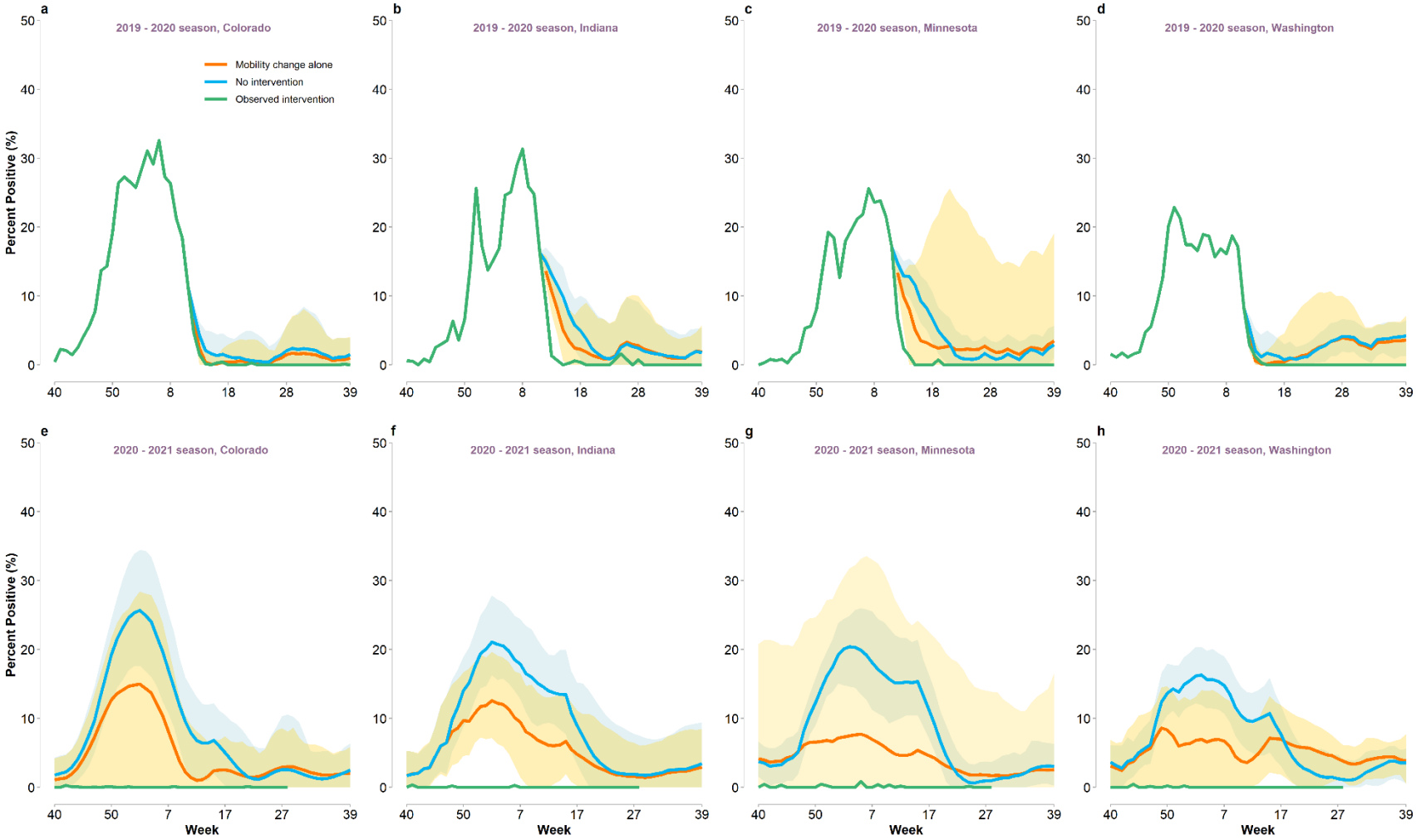
Extended Data Fig. 16 Fitted influenza activity that is obtained from using the 2011-2018 data for training and the 2019 data for test, in comparison to observed influenza activity.



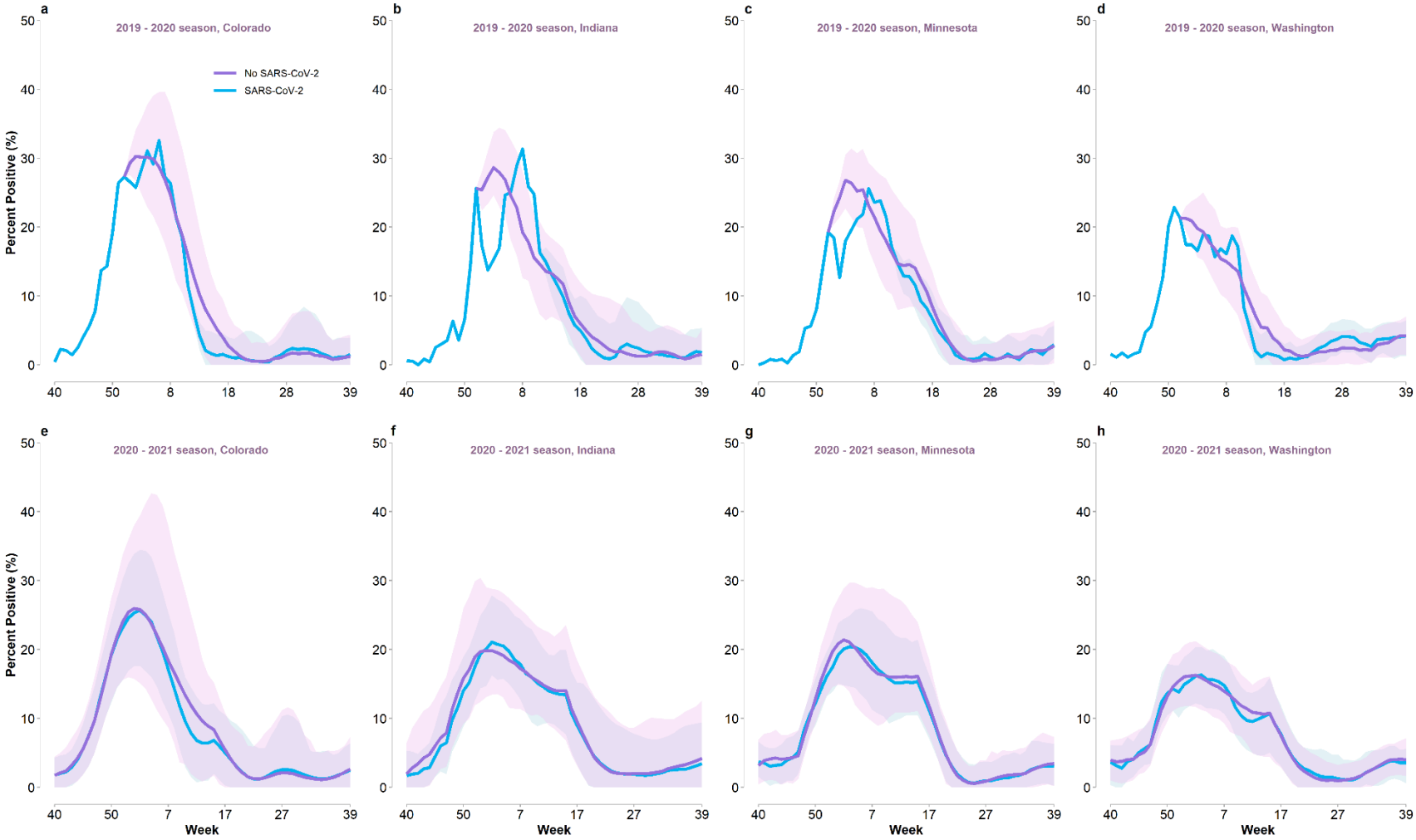
Extended Data Fig. 17 Influenza activity across four US states. a Observed and fitted influenza activities in Colorado. **b** As **a**, but in Indiana. **c** As **a**, but in Minnesota. **d** As **a**, but in Washington.



Extended Data Fig. 18 Estimated influenza activities across four US states under the mask-wearing order alone and no intervention as well as the observed activity. **a** Weekly percent positivity in 2019-2020 season for Colorado. **b** As **a**, but for Indiana. **c** As **a**, but for Minnesota. **d** As **a**, but for Washington. **e** As **a**, but in 2020-2021. **f** As **e**, but for Indiana. **g** As **e**, but for Minnesota. **h** As **e**, but for Washington. Shaded area refer to 95% CI.



Extended Data Fig. 19 Estimated influenza activities across four US states under the mobility change alone and no intervention as well as the observed activity. **a** Weekly percent positivity in 2019-2020 season for Colorado. **b** As **a**, but for Indiana. **c** As **a**, but for Minnesota. **d** As **a**, but for Washington. **e** As **a**, but in 2020-2021. **f** As **e**, but for Indiana. **g** As **e**, but for Minnesota. **h** As **e**, but for Washington. Shaded area refer to 95% CI.



Extended Data Fig. 20 Estimated influenza activities across four US states under the scenarios with no SARS-COV-2 transmission and with SARS-COV-2 transmission, both without COVID-19 NPIs. a Weekly percent positivity in 2019-2020 season for Colorado. **b** As **a**, but for Indiana. **c** As **a**, but for Minnesota. **d** As **a**, but for Washington. **e** As **a**, but in 2020-2021. **f** As **e**, but for Indiana. **g** As **e**, but for Minnesota. **h** As **e**, but for Washington. Shaded area refer to 95% CI.

Extended Data Fig. 21 Predicted influenza activities across four US states in 2021-2022 season under no NPI and varying NPIs. a Weekly percent positivity under mask-wearing intervention for the full season in Colorado. **b** As **a**, but for Indiana. **c** As **a**, but for Minnesota. **d** As **a**, but for Washington. **e** As **a**, but under international mobility mitigation reduced by 50%. **f** As **e**, but for Indiana. **g** As **e**, but for Minnesota. **h** As **e**, but for Washington. **i** As **a**, but under domestic mobility mitigation reduced by 50%. **j** As **i**, but for Indiana. **k** As **a**, but for Minnesota. **l** As **a**, but for Washington. Shaded area refer to 95% CI.

Table S1 Estimated effects for one-week increase of NPIs, the lag of mask-wearing interventions included and the percentage of the effects due to mobility change attributable to the international travel mitigation.

	Northern China		Southern China		England		The U.S.	
	Mean	95%CI	Mean	95%CI	Mean	95%CI	Mean	95%CI
One-week increase in the precent reduction								
Mask-wear intervention	29·5	(26·6, 32·2)	35·2	(31·5, 38·6)	11·3	(9·0, 13·7)	12·2	(9·4, 14·7)
Domestic mobility	2·0	(-1·7, 7·8)	2·8	(-2·3, 9·3)	1·6	(0·0, 13·1)	2·6	(0·0, 14·1)
International mobility	4·5	(2·3, 6·9)	1·7	(0·5, 2·9)	6·5	(2·5, 10·7)	3·3	(1·3, 5·2)
Lag of intervention included								
Mask-wearing intervention	13	——[a]	11	——[a]	24	——[a]	35	——[a]
Mobility effect attributable to the international mitigation measure								
2019-2020 influenza season	80·4	(41·6, 100·0)	60·0	(0·0, 100·0)	89·3	(37·7, 100·0)	80·5	(26·3, 100·0)
2020-2021 influenza season	96·0	(80·5, 100·0)	98·2	(87·5, 100·0)	93·6	(62·0, 100·0)	79·8	(26·3, 100·0)

Notes: a. Best fitted based on R^2criteria.

Table S2 Summary of data

Data	Description	Baseline value	Reference
Y_t^{mob}	Influenza percent positivity at time *t* under the mobility change only	Extended Data Fig. 1	2–4
V_t	Domestic mobility at time *t*	Extended Data Fig. 10	5–8
W_t	International mobility at time *t*	Extended Data Fig. 10	7,9,10
S_t	Indicator of influenza season at time *t*	Estimated from influenza activity	2–4
N	Number of the lag of influenza activity included in Model (1)	52	
Mask index	Mask-wearing intervention	Extended Data Fig. 11	11–13
r_t	Cumulative COVID-19 vaccine does at time t	Extended Data Fig. 12	14–16
D_t^{mas}	Mask-wearing intervention adjusted by vaccination coverage	Derived through Mask index through Equation (3)	
I	Indicator of the existence of minor NPI along with mask-wearing intervention	1 during the NPI period, 0 otherwise	11–13
Y_t^{npi}	Influenza percent positivity at time *t* under the all NPIs	Extended Data Fig. 1	2–4
L	Number of the lag of mask-wearing intervention included in Model (2)	Table S1	
M	Number of the lag of mobility used in the moving average method	4 for China; 2 for England and the U.S.	
μ	Decreasing rate of mask-wearing intervention with the vaccination coverage	Best fitted based on R^2criteria	
δ	Immediate reduction of mask-wearing intervention with the vaccination coverage	Best fitted based on R^2criteria	

Table S3 The Pearson's correlation between domestic mobility change during the COVID-19 pandemic and the domestic movement restriction level, and the correlations between mobility related NPIs from the Oxford COVID-19 Government Response Tracker.

	Northern China		Southern China		England		The U.S.	
	Estimate	P-value[a]	Estimate	P-value[a]	Estimate	P-value[a]	Estimate	P-value[a]
Correlation between domestic mobility change and								
Domestic movement restriction	0·518	p < 0·0001	0·715	p < 0·0001	0·408	p = 0·002	0·487	p < 0·0001
Correlation between domestic movement restriction and								
School-closing	0·806	p < 0·0001	0·671	p < 0·0001	0·667	p < 0·0001	0·882	p < 0·0001
Workplace closing	0·894	p < 0·0001	0·681	p < 0·0001	0·862	p < 0·0001	0·910	p < 0·0001
Cancel public events	0·934	p < 0·0001	0·853	p < 0·0001	0·775	p < 0·0001	0·956	p < 0·0001
Restrictions on gatherings	0·848	p < 0·0001	0·827	p < 0·0001	0·738	p < 0·0001	0·824	p < 0·0001
Close public transport	0·924	p < 0·0001	0·920	p < 0·0001	0·718	p < 0·0001	0·873	p < 0·0001
Stay at home	0·851	p < 0·0001	0·746	p < 0·0001	0·848	p < 0·0001	0·824	p < 0·0001

Notes: a. P value calculated by two-sided t-test.

Reference

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