# Supporting Information

## Face mask mandates and risk compensation: An analysis of mobility data during the COVID-19 pandemic in Bangladesh

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**Table S-1 (a): Descriptive statistics of six mobility measures for the time period between 2 June 2020 to 21 July 2020**

|  | Retail and recreation | Grocery and pharmacy | Parks | Transit stations | Workplaces | Residential |
|---|---|---|---|---|---|---|
| Mean | -40.62 | -21.74 | -22.84 | -37.8 | -18.46 | 13.28 |
| Standard Error | 0.95 | 0.82 | 0.52 | 0.68 | 1.06 | 0.21 |
| Median | -41.5 | -22.5 | -22.5 | -39 | -20 | 13 |
| Mode | -43 | -25 | -22 | -40 | -26 | 14 |
| Standard Deviation | 6.69 | 5.76 | 3.69 | 4.8 | 7.49 | 1.46 |
| Sample Variance | 44.69 | 33.22 | 13.65 | 23.02 | 56.09 | 2.12 |
| Kurtosis | -0.81 | -0.34 | 0.1 | -0.4 | 0.54 | 0.39 |
| Skewness | 0.17 | 0.02 | -0.55 | -0.04 | 1.05 | 0.11 |
| Range | 26 | 25 | 15 | 20 | 32 | 7 |
| Minimum | -53 | -36 | -32 | -49 | -29 | 10 |

**Table S-1 (b): Descriptive statistics of daily new cases and six mobility measures for the time period between 10 April 2020 to 31 October 2020**

|  | Daily new case | Retail and recreation | Grocery and pharmacy | Parks | Transit stations | Workplaces | Residential |
|---|---|---|---|---|---|---|---|
| Mean | 1987.09 | -35.31 | -15.12 | -14.63 | -30.6 | -20.65 | 13.05 |
| Standard Error | 69.63 | 1.51 | 1.51 | 1.02 | 1.62 | 1.32 | 0.38 |
| Median | 1873 | -31 | -12 | -17 | -30 | -16 | 12 |
| Mode | 1541 | -19 | -1 | -3 | -17 | -8 | 9 |
| Standard Deviation | 996.92 | 21.55 | 21.63 | 14.56 | 23.12 | 18.92 | 5.48 |
| Sample Variance | 993855.2 | 464.4 | 467.97 | 211.97 | 534.7 | 358.1 | 30.08 |
| Kurtosis | -0.88 | -1.06 | -0.87 | -1.07 | -1.02 | -0.41 | 0.02 |
| Skewness | 0.05 | -0.46 | -0.35 | 0.03 | -0.26 | -0.79 | 0.98 |
| Range | 3961 | 77 | 90 | 65 | 83 | 77 | 23 |
| Minimum | 58 | -77 | -56 | -42 | -73 | -66 | 4 |
| Maximum | 4019 | 0 | 34 | 23 | 10 | 11 | 27 |

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**Table S-2: Time series model estimation for different mobility measures using 2 June 2020 to 21 July 2020 data.** These models are used for the predictions between 22-28 July, which are then compared with actual observations in Table 1 in the main text.

| | Model: 1a | | Model: 1b | | Model: 1c | | Model: 1d | | Model: 1e | | Model: 1f | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mobility type as dependent variable → | Retail and recreation | | Grocery and pharmacy | | Parks | | Transit stations | | Workplaces | | Residential | |
| Parameters ↓ | Coef. | 95% CI | Coef. | 95% CI | Coef. | 95% CI | Coef. | 95% CI | Coef. | 95% CI | Coef. | 95% CI |
| AR – Lag 1 | 0.65*** | (0.35 to 0.94) | 0.57*** | (0.24 to 0.91) | 0.49*** | (0.17 to 0.8) | 0.62*** | (0.31 to 0.93) | -- | -- | -0.07 | (-0.32 to 0.19) |
| AR – Lag 7 | -- | -- | -- | -- | -- | -- | -- | -- | 0.87*** | (0.72 to 1.01) | 0.52*** | (0.25 to 0.8) |
| MA – Lag 3 | -- | -- | -- | -- | -- | -- | -- | -- | -0.14 | (-0.51 to 0.23) | -- | -- |
| Weekend | -3.42*** | (-5.08 to -1.77) | -0.49 | (-2.46 to 1.48) | -1.28 | (-3 to 0.44) | -0.74 | (-2.28 to 0.8) | 13.1*** | (7.54 to 18.66) | -1.02* | (-2.16 to 0.13) |
| Trend | 0.35*** | (0.22 to 0.49) | 0.27*** | (0.14 to 0.41) | 0.12*** | (0.03 to 0.22) | 0.22*** | (0.1 to 0.35) | 0.21*** | (0.14 to 0.28) | -0.05*** | (-0.08 to -0.03) |
| Intercept | -48.79*** | (-52.8 to -44.77) | -28.66*** | (-32.85 to -24.47) | -25.64*** | (-28.29 to -22.99) | -43.36*** | (-46.71 to -40.01) | -26.77*** | (-31.2 to -22.34) | 14.85*** | (14.02 to 15.68) |
| **Model Statistics** | | | | | | | | | | | | |
| Observations | 50 | | 50 | | 50 | | 50 | | 50 | | 50 | |
| AIC | 246.48 | | 265.29 | | 246.41 | | 241.02 | | 219.74 | | 144.94 | |
| MAPE (%) | -4.70 | | -11.43 | | -8.79 | | -4.83 | | -10.16 | | 5.34 | |
| Ljung and Box Q (p-value) | 22.46 (0.49) | | 11.1 (0.98) | | 26.40 (0.28) | | 22.92 (0.47) | | 15.88 (0.86) | | 28.71 (0.19) | |
| Augmented Dickey-Fuller test stat (p-value) | -3.781 (0.02) | | -3.34 (0.06) | | -4.802 (<0.001) | | -3.412 (0.049) | | -5.675 (<0.001) | | -4.114 (0.006) | |

Note: *** statistically significant at 99% confidence, ** statistically significant at 95% confidence, * statistically significant at 90% confidence
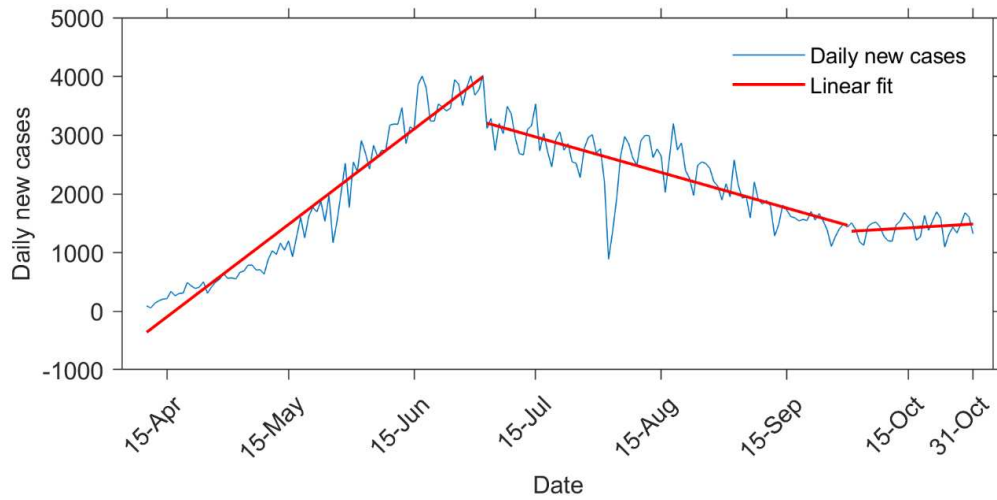
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**Figure S-1: Linear fit of daily new case data showing change of slope. Abrupt change in linear slope is used to identify the regime change as discussed in literature (Killick, Fearnhead, & Eckley, 2012).** The analysis was carried out in MATLAB by considering the changes in slope as the objective function. The method described in the literature are built into MATLAB as a function. That function "ischange" is used to identify the abrupt change in slope.
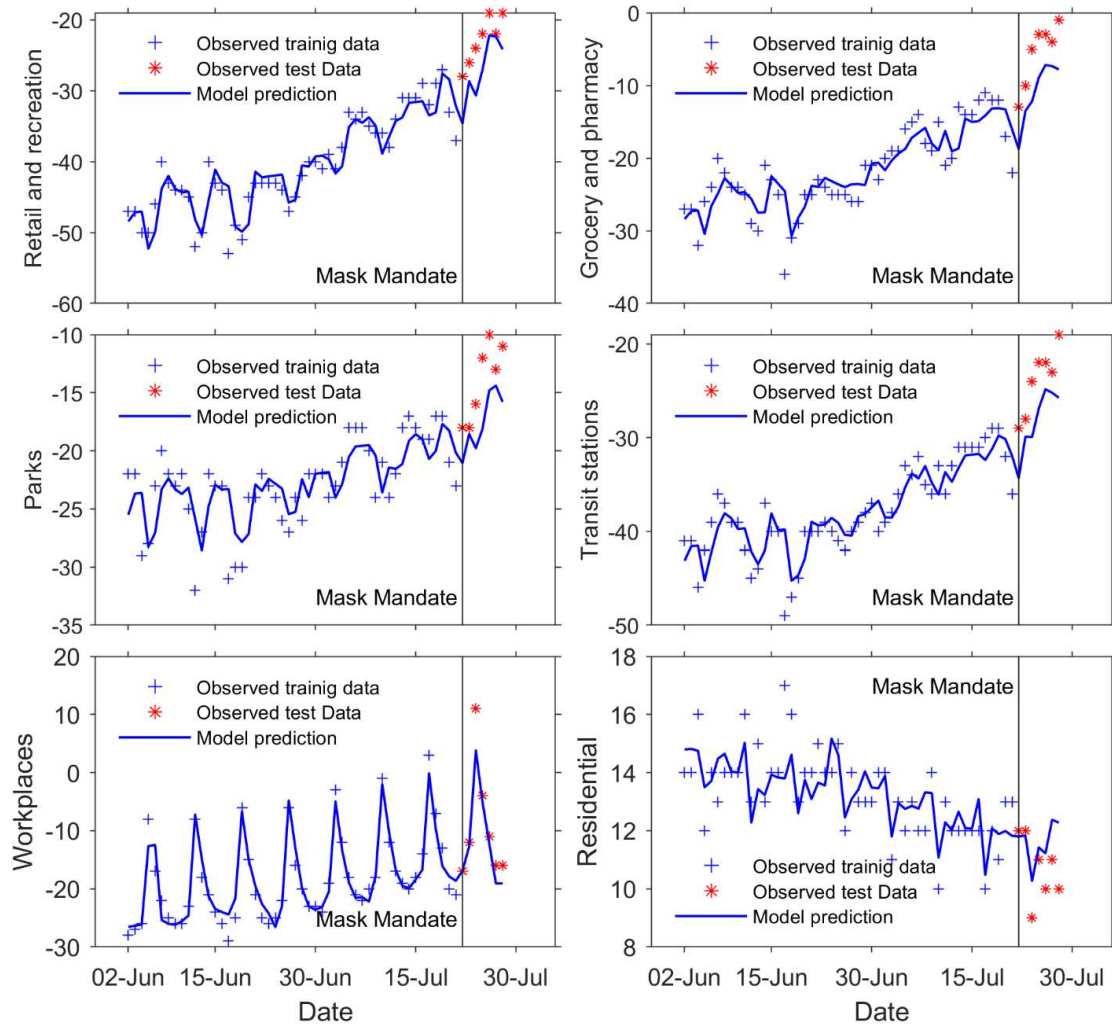
**Figure S-2: Observed and model prediction mobility changes for the period between 2 June to 28 July 2020.** These figures corroborates the findings of Table 1 in the main text that post-intervention the actual observations are consistently different from the model predictions.

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**Table S-3: Falsification test: divergences in model estimated and observed mobility measures by bringing forward the mask intervention by 1 and 3 days.** These models were run, and predictions were compared with actual data in order to test that the changes occurred from the day of the intervention, and not before that. Results indeed show statistically insignificant divergence between predicted and observed values for these 2 test intervention dates.

| Mobility type as dependent variable → | Retail and recreation | Grocery and pharmacy | Parks | Transit stations | Workplaces | Residential |
|---|---|---|---|---|---|---|
| **7-day prediction with mask intervention forwarded by one (1) day: Mandatory mask intervention begins on 21 July 2020 and prediction for the period between 21 July to 27 July 2020** | | | | | | |
| Observed mean | -25.43 | -8.57 | -15.71 | -26.29 | -10.00 | 11.14 |
| Predicted mean | -27.90 | -11.55 | -17.90 | -28.67 | -11.25 | 11.47 |
| Difference of mean (One-sided 95% confidence interval) | 2.47 (-0.53 to Inf) | 2.98 (-0.27 to Inf) | 2.19 (-0.04 to Inf) | 2.38 (-0.11 to Inf) | 1.25 (-1.05 to Inf) | -0.33 (-Inf to 0.58) |
| Alternative hypothesis | Observed value is higher | Observed value is higher | Observed value is higher | Observed value is higher | Observed value is higher | Observed value is lower |
| t-stat (p-value) | 1.6 (0.08) | 1.78 (0.063) | 1.91 (0.053) | 1.86 (0.056) | 1.05 (0.166) | -0.71 (0.253) |
| **7-day prediction with mask intervention forwarded by three (3) day: Mandatory mask intervention begins on 19 July 2020 and prediction for the period between 19 July to 25 July 2020** | | | | | | |
| Observed mean | -28.14 | -11.71 | -17.86 | -28.57 | -10.86 | 11.57 |
| Predicted mean | -29.02 | -12.89 | -18.61 | -29.91 | -11.32 | 11.39 |
| Alternative hypothesis | Observed value is higher | Observed value is higher | Observed value is higher | Observed value is higher | Observed value is higher | Observed value is lower |
| Difference of mean (One-sided 95% confidence interval) | 0.88 (-2.73 to Inf) | 1.18 (-2.57 to Inf) | 0.75 (-1.71 to Inf) | 1.34 (-1.46 to Inf) | 0.46 (-1.94 to Inf) | 0.18 (-Inf to 0.91) |
| t-stat (p-value) | 0.47 (0.327) | 0.61 (0.283) | 0.59 (0.287) | 0.93 (0.194) | 0.37 (0.361) | 0.5 (0.682) |

**Table S-4: Robustness test: divergences in model estimated and observed mobilities using the model developed with the data from 2 June 2020 to 14 July 2020.** Data from the period between 15 July 2020 to 21 July 200 is used as a separate validation set and data between 22 July 2020 to 28 July 2020 as the test dataset for testing the mask mandate effect. From the statistical significance test, it has been observed that divergence of the predicted values from the observed values are statistically significant for the test dataset, while the divergence was statistically insignificant for the validation dataset. Differences in the 7-day predictions with actual activities for all six mobility indicators are statistically insignificant for the 1-week period before the day of mask mandate, while they are statistically significant for the 1-week period from the mask mandate day (22 July 2020). This indicates that, divergence from the model predicted values from the observed values is lower for the 1-week period before the day of mask mandate than the 1 week from the mask mandate day (22 July 2020).

| Mobility type as dependent variable → | Retail and recreation | Grocery and pharmacy | Parks | Transit stations | Workplaces | Residential |
|---|---|---|---|---|---|---|
| **7-day prediction for validation dataset for the period between 15 July 2020 to 21 July 2020** | | | | | | |
| Observed mean | -31.14 | -14.29 | -19.14 | -31.14 | -12.86 | 11.86 |
| Predicted mean | -31.12 | -14.30 | -19.29 | -31.45 | -14.32 | 11.93 |
| Difference of mean (One-sided 95% confidence interval) | -0.02 (-2.61 to Inf) | 0.01 (-2.65 to Inf) | 0.15 (-1.55 to Inf) | 0.31 (-1.47 to Inf) | 1.46 (-0.35 to Inf) | -0.07 (-Inf to 0.58) |
| Alternative hypothesis | Observed value is higher | Observed value is higher | Observed value is higher | Observed value is higher | Observed value is higher | Observed value is lower |
| t-stat (p-value) | -0.02 (0.507) | 0.01 (0.496) | 0.17 (0.435) | 0.34 (0.374) | 1.56 (0.084) | -0.22 (0.417) |
| RMSE | 10.60 | 11.29 | 4.62 | 5.09 | 7.35 | 0.67 |
| **7-day prediction for mandatory mask test dataset for the period between 22 July 2020 to 28 July 2020** | | | | | | |
| Observed mean | -22.86 | -5.57 | -14.00 | -23.86 | -9.29 | 10.71 |
| Predicted mean | -27.17 | -11.00 | -17.66 | -28.39 | -12.02 | 11.62 |
| Difference of mean (One-sided 95% confidence interval) | 4.31 (2.66 to Inf) | 5.43 (4.2 to Inf) | 3.66 (2.14 to Inf) | 4.53 (3.08 to Inf) | 2.73 (0.92 to Inf) | -0.91 (-Inf to -0.23) |
| Alternative hypothesis | Observed value is higher | Observed value is higher | Observed value is higher | Observed value is higher | Observed value is higher | Observed value is lower |
| t-stat (p-value) | 5.07 (0.001) | 8.56 (<0.001) | 4.68 (0.002) | 6.07 (<0.001) | 2.93 (0.013) | -2.62 (0.02) |
| RMSE | 22.98 | 31.93 | 17.10 | 23.88 | 12.69 | 1.53 |

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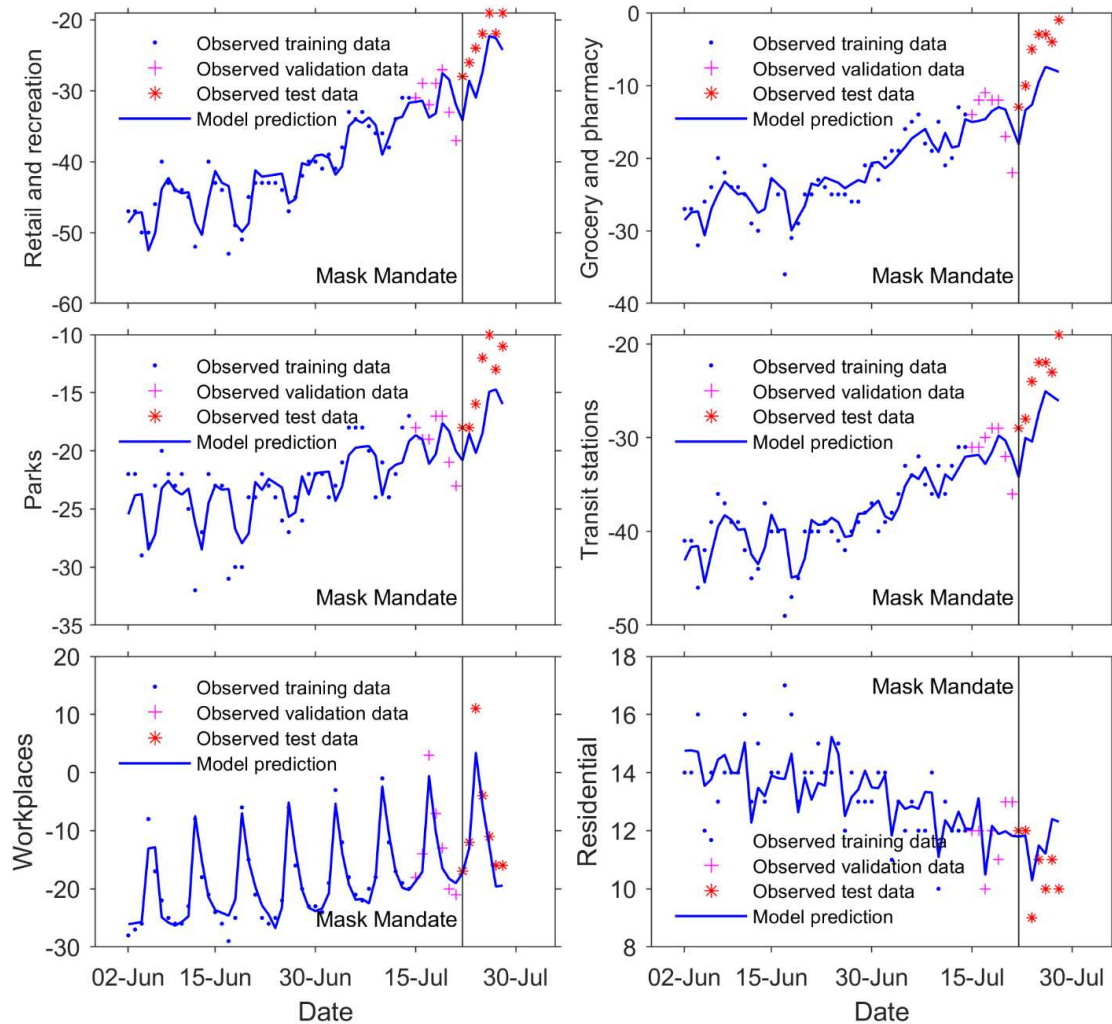
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**Figure S-3: Observed and model prediction mobility changes for the training, validation, and test dataset. (**The model is prepared using the training dataset from the period between 2 June to 14 July 2020. Validation dataset is from the period between 15 July to 21 July 2020 and test dataset is from the period between 21 July to 28 July 2020. For the validation period, there is no 'systematic divergence'; for the post-intervention period, there is.)

**Table S-5: Parameter estimates for the association between mobility and COVID-19 infection. 95% confidence interval of coefficients are shown in the parenthesis.** These models are the best models, selected based on adjusted $R^2$ and AIC values, among various lag days between new infection and percent mobility changes. Though the magnitude of coefficient changed slightly, there is no change in sign of various parameters between these models and models with 10-day lag between infection and mobility. The statistical significance are improved slightly, for a few parameters.

| | Model: 2a | Model: 2b | Model: 2c | Model: 2d | Model: 2e | Model: 2f |
|---|---|---|---|---|---|---|
| **Mobility type as independent variable →** | **Retail and recreation** | **Grocery and pharmacy** | **Parks** | **Transit stations** | **Workplaces** | **Residences** |
| **Mobility lag(days)** | 12 | 12 | 9 | 10 | 12 | 10 |
| **Parameters ↓** | **Coefficient (95% CI)** | **Coefficient (95% CI)** | **Coefficient (95% CI)** | **Coefficient (95% CI)** | **Coefficient (95% CI)** | **Coefficient (95% CI)** |
| Daily new cases – Lag 1 | 0.43*** (0.3 to 0.56) | 0.39*** (0.26 to 0.53) | 0.33*** (0.19 to 0.48) | 0.39*** (0.25 to 0.53) | 0.45*** (0.32 to 0.58) | 0.41*** (0.28 to 0.54) |
| Mobility | 9.25*** (2.95 to 15.55) | 10.2*** (5.15 to 15.24) | 14.42*** (8 to 20.84) | 14.3*** (5.4 to 23.19) | 1.76 (-2.15 to 5.68) | -35.73*** (-51.57 to -19.89) |
| Eid_outlier | -830.28** (-1553.41 to -107.15) | -830.77** (-1524.3 to -137.24) | -920.76*** (-1613.5 to -228.01) | -902.13** (-1627.45 to -176.81) | -785.34** (-1559.5 to -11.19) | -845.51** (-1580.84 to -110.18) |
| Weekend | -179.4*** (-250.92 to -107.88) | -168.97*** (-237.56 to -100.39) | -125.21*** (-193.26 to -57.15) | -152.77*** (-223.61 to -81.94) | -155.76*** (-230.67 to -80.84) | -138.68*** (-210.54 to -66.81) |
| Free_test_stopped – Lag 3 | -435.2*** (-628.55 to -241.86) | -445.83*** (-633.18 to -258.48) | -486.38*** (-676.88 to -295.88) | -411.19*** (-597.23 to -225.16) | -387.28*** (-570.57 to -203.98) | -406.71*** (-590.18 to -223.23) |
| Trend 1 (Apr 1 to Oct 31, 2020) | 26.63*** (20.55 to 32.7) | 28.15*** (21.9 to 34.41) | 33.09*** (25.81 to 40.37) | 25.59*** (19.08 to 32.1) | 28.22*** (21.16 to 35.28) | 25.35*** (18.91 to 31.78) |
| Trend 2 (Jul 3 to Oct 31, 2020) | -41.82*** (-51.16 to -32.48) | -44.26*** (-53.88 to -34.65) | -51.31*** (-62.27 to -40.35) | -43.54*** (-53.41 to -33.67) | -40.28*** (-49.96 to -30.59) | -39.86*** (-48.92 to -30.8) |
| Trend 3 (Oct 1 to Oct 31, 2020) | 15.65*** (9.26 to 22.05) | 14.78*** (8.77 to 20.8) | 22.19*** (15.31 to 29.07) | 13.26*** (7.49 to 19.02) | 12.62*** (6.83 to 18.41) | 15.71*** (10.08 to 21.33) |
| Intercept | -140.77 (-649.94 to 368.41) | -344.17** (-658.26 to -30.07) | -573.17*** (-859.01 to -287.34) | 228.75 (-469.65 to 927.16) | -797.66*** (-1169.42 to -425.9) | 87.97 (-374.79 to 550.73) |
| **Model Statistics** | | | | | | |
| Observations | 204 | 204 | 204 | 204 | 204 | 204 |
| Adjusted $R^2$ | 0.9371 | 0.9388 | 0.941 | 0.9392 | 0.9347 | 0.9395 |
| AIC | 2837.80 | 2832.34 | 2824.97 | 2831.09 | 2845.28 | 2829.82 |

Notes: Dependent variable: Daily new cases in Bangladesh.

\*\*\* statistically significant at 99% confidence, \*\* statistically significant at 95% confidence, \* statistically significant at 90% confidence

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**Table S-6: Model estimation results for association between COVID-19 infection and external interventions.** Most external interventions show intended effects on COVID-19 spread. Mandatory mask has a parameter estimate statistically not different from zero, indicating apparently full compensation effect. However, this result is not due to 'risk compensation' alone, rather due to a combination of risk compensation, lack of adherence to mask mandate, use of poor quality masks or poorly worn masks and lack of monitoring and enforcement. More detailed explanation of this model is available in our research report (Wadud, Rahman, & Enam, 2021). This exploratory regression shows that inadequate implementation of mandates could nullify the expected benefits of mask wearing.

| Parameters | Coefficient (95% CI) |
|---|---|
| Daily new cases – Lag 1 | 0.2** (0.04 to 0.36) |
| Garments closure – Lag 10 | 117.01  (-56.83 to 290.86) |
| Garments open dilemma – Lag 10 | 138.78*** (33.12 to 244.44) |
| Shopping mall closure – Lag 10 | -362.1*** (-592.46 to -131.74) |
| Office closure – Lag 10 | -541.31** (-1041.18 to -41.45) |
| Office half capacity – Lag 10 | -168.93  (-462.38 to 124.51) |
| Public transport half capacity – Lag 10 | 74.07  (-129.82 to 277.96) |
| Mandatory mask mandate – Lag 10 | 202.35  (-102.38 to 507.09) |
| Eid ul Fitr Day – Lag 10 | 291.25* (-12.23 to 594.73) |
| Eid ul Adha Day – Lag 10 | 222.39  (-79.27 to 524.06) |
| Eid_outlier | -1098.17*** (-1839.33 to -357.01) |
| End of Free test facility – Lag 3 | -515.52*** (-759.87 to -271.18) |
| Friday | -0.89  (-82.18 to 80.4) |
| Trend 1 (April 1 to October 31, 2020) | 30.95*** (21.1 to 40.8) |
| Trend 2 (July 3 to October 31, 2020) | -52.44*** (-66.78 to -38.1) |
| Trend 3 (October 1 to October 31, 2020) | 27.14*** (15.79 to 38.49) |
| Intercept | -121.18  (-1022.76 to 780.41) |
| **Model Statistics** | |
| Observations | 204 |
| Adjusted $R^2$ | 0.9376 |
| AIC | 2843.92 |
| MAPE (%) | 12.2 |
| Augmented Dickey-Fuller test stat (p-value) | -6.193 (<0.001) |

Note: *** statistically significant at 99% confidence, ** statistically significant at 95% confidence, * statistically significant at 90% confidence

## References

Killick, R., Fearnhead, P., & Eckley, I. A. (2012). Optimal Detection of Changepoints With a Linear Computational Cost. *Journal of the American Statistical Association, 107*(500), 1590-1598.

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