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Does the introduction of a mandatory policy on face mask use elicit risk-compensation? Evidence from Denmark during the SARS-CoV-2 pandemic using an instrumental variable approach

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Background: Public use of face masks has been widely adopted to halter the SARS-CoV-2 pandemic but a key concern has been whether the effectiveness of face mask use is limited due to elicitation of false feelings of security that decrease the observance of other protective behaviors, so-called risk-compensation.

Methods: We take an instrumental variable approach to assess whether public use of face masks elicit risk-compensation by decreasing attention to distancing and hygiene. In particular, we use the onset of a mandatory policy to wear face masks in public transportation in Denmark as an instrument for actual face mask use in daily nationally representative surveys (N = 32,504).

Findings: The use of face mask does not influence people's attention to hygiene or the number of close contacts but does decrease people's attention to distancing and, specifically, their attention to avoiding places and activities involving many people.

Interpretations: Face masks elicit a narrow form of risk-compensation such that people are more likely to seek out those specific settings in which face masks offer additional protection. To increase the effectiveness of face masks, the onset of mandatory face mask policies should be combined with clear health communication to counter this form of risk-compensation.

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To contain the SARS-CoV-2 pandemic, WHO has encouraged the general use of facial masks in settings with "widespread community transmission" and "where physical distancing cannot be maintained" (WHO, 2020). Nonetheless, a number of countries have been reluctant to adopt this policy, questioning the efficacy of facial masks as a protective device for the general public (Erdbrink, 2020), and some countries, e.g., the Scandinavian countries, have observed very low use of face masks (YouGov, 2020). The discussion has focused on how the effectiveness of the public's use facial masks is a function of features beyond their mechanical ability to filter viral particles and, in particular, whether and how mask use shapes the behavior of the wearer and bystanders, respectively. As noted by Peeples (2020), "human behaviour is core to how well masks work in the real world." Concerns have been raised that the effectiveness of masks may be reduced by generating a "false sense of security" or what is often in the psychological literature referred to as risk-compensation, i.e., that the adoption of one precautionary measure down-regulates feeling of threat, which in turn elicits more risky behavior (Mantzari et al., 2020; Peeples, 2020).

Given the nature of the pandemic situation, few studies on the effectiveness of public mask use during the SARS-CoV-2 pandemic are available. The few existing studies suggest the public use of face masks is efficient to decrease infection spread despite potential dynamics related to risk-compensation (Chu et al., 2020). Furthermore, randomized controlled experiments suggest that mask use does not lead bystanders to engage in risk-compensation (Seres et al., 2020a, 2020b). In fact, bystanders keep a slightly larger distance to mask-wearers than non-mask-wearers. At the same time, we know virtually nothing about the key concern from a risk-compensation perspective (Peeples, 2020): If and how mask use shapes the behavior of wearers' themselves? One review of studies outside of the SARS-CoV-2 pandemic finds evidence that mask-wearing does not decrease focus on hand hygiene (Mantzari et al., 2020). A single study during the SARS-CoV-2 pandemic from Germany finds that the motivation to use masks is positively associated with the motivation keep 1.5 meters of distance to others (Betsch et al., 2020). Yet, neither of these studies address the core concern: Does policies that promote the general use of face masks in public settings increase mask-wearers tendency to seek out such settings?

There are several challenges to answering this research question. The first is the need to rely on observational design rather than randomized experiments, given ethical concerns over randomizing access to protection during a pandemic. The second relates to causality: WHO recommends the use of masks in public settings where distance cannot be maintained. Accordingly, even a non-risk-compensating use of masks would imply a positive association between mask use and visiting crowded places. This implies that it is key to determine whether the promotion of masks makes people more likely to use masks in crowded settings that they would visit in any case; or whether people are more likely to visit crowded settings upon the promotion of masks.

In this study, we discern between these potential effects of mask-usage on the behavior of the wearer by utilizing a change in the policies regarding mask use in Denmark. This context is ideally suited for understanding how mask usage influence behavior in naive populations, as Denmark has no history of general use of masks prior to the SARS-CoV-2 pandemic. Until July 31 2020, the Danish national health authority only recommended the use of face masks under special circumstances (e.g., if you tested positive for SARS-CoV-2 or had symptoms and need breaking self-isolation in order to transport yourself to the hospital) (Sundhedsstyrelsen, 2020a). On July 31 2020, the Danish national health authority started recommending the use of face masks in public transportation during rush hour (Sundhedsstyrelsen, 2020b). On August 22 (announced August 15), the government changed this recommendation into a mandatory policy to use face masks *at all times* in public transportation, generating a massive uptick in the use of face masks in the Danish population (see Figure 1).

Empirically, we utilize a unique survey study with daily, large-scale representative surveys of Danes during the SARS-CoV-2 pandemic (N=32,504). This data includes questions about mask use, the number of infection-relevant contacts, attention to keeping a distance, and attention to hygiene. First, we analyze how face mask use across the policy changes correlates with the individual-level indicators of other protective behaviors. Second, the policy changes constitute a situation akin to a natural experiment that allows us to provide evidence on the question of causality. Specifically, we use the Danish policy changes in an instrumental variables (IV) strategy to identify the effects of mask use on the number of infection-relevant contacts, attention to keeping a distance, and attention to hygiene.

Methods

Study design and participants

Our data are collected by the survey company Kantar Gallup. Data collection started on May 13, with new waves of approximately unique 500 unique respondents each day. Table S.1 in the SI gives an overview of the actual number of sampled respondents per day. We started surveying the use of face mask from July 20 and analyses in this study is based on data from July 20 until September 8 (N = 32,504).

Participants are Danish citizens aged 18 or older. They are recruited using stratified random sampling—on age, sex, and geography—based on the entire database of Danish social security numbers, delivered by Statistics Denmark (DST). The recruited participants are thus representative of the broader Danish population in regards to these characteristics. The average response rate is 49 percent. Table S.2 in the SI provides a detailed overview of response rates by sex and age groups. The data is collected using an electronic survey, delivered through participants via e-Boks (a nation-wide Danish electronic mail system).

Measures

All measures are self-reported from participant questionnaires. The key measures are mask use, contact behavior, distance attention, and hygiene attention. Mask use is measured by a single question, while the remaining protective behaviors are measures using indices based on several questions. Questions, values, descriptives and scale reliabilities are provided in Table 1. Participants who answered that they have used a mask one or more times within the last week are classified as a mask-user. On contact behavior, we control the influence of outlying observations by ceiling off each of the individual contact measures at the 99th percentile before generating the overall contact index. On the remaining indices, we add together the individual questions into reliable scales of the underlying protective behaviors. "Do not know" answers are classified as missing. In the table below, we report "raw" descriptives, i.e., the mean and standard deviation based on the unstandardized measures. In the statistical analyses, we center each of the indices on their mean and standardize them with a standard deviation of 1.

The analyses include a set of sociodemographic variables: Age, gender (0 for males; 1 for females), education (0 for non-tertiary education; 1 for tertiary education), and municipality of residence. Moreover, we include a measure of threat appraisal, indicating to what degree participants feel that the corona virus personally threatens them themselves and to what degree they feel it is a threat to the society. For descriptions of these measures, see Table S.3 in the SI.

Table 1: Main measures in the study

	Questions	Values	Mean/SD/scale reliability
Mask use	How many times have you used a face mask within the last week?	1. I have not used a face mask 2. 1-3 times 3. 4-6 times 4. 7-9 times 5. 10 times or more	0.34/0.47/NA
Contact behavior	We are interested to hear how many other people you have been physically close to in the past 24 hours. Physically close is here understood to be closer than 1 meters for at least 15 minutes. Please give us your best guess. • How many from your family that you do not live with have you been physically close to? • How many colleagues have you been physically close to? • How many friends and acquaintances (ie people you know the name of) have you been physically close to? • How many have you been physically close to that you didn't already know? (for example, in public transport, playgrounds, in supermarkets)	Numeric	6.68/12.08/0.47
Distance attention	To what extent were you yesterday aware to? • Avoid physical contact. • Keep away from elderly and chronically ill people. • Keep 1-2 meters distance to other people. • Minimize your going to places, where many people typically are going. • Minimize activities where you have contact to other people.	1. Not at all 2. 3. 4. 5. 6. 7. To a high degree 8. Don't know	5.47/1.26/0.84
Hygiene attention	To what extent were you yesterday aware to? • Ensure good hand hygiene by washing your hands frequently or using hand sprays. • Ensure frequent and thorough cleaning. • Cough or sneeze in your sleeve.	1. Not at all 2. 3. 4. 5. 6. 7. To a high degree 8. Don't know	6.00/1.00/0.62

Note: Scale reliability is measured by α. NA=not applicable.

Role of funding source

The study was funded by a grant from the Carlsberg Foundation (the principal shareholder in Carlsberg A/S). The foundation uses part of its dividends to fund and support research. The Carlsberg Foundation had no role in the design, data collection, analyses or writing of this study.

Statistical analysis

To assess whether the use of face masks leads to risk-compensation, we initially analyze whether the correlations between face mask use and other types of protective behaviors are indicative of potential risk-compensation. To gauge causality, we then employ an IV strategy that exploits the changes to Danish face mask policy to identify the causal effects of face mask use on the other protective behaviors.

For the correlational results, we develop a multilevel regression model that allows the intercepts and slopes of each correlates to vary over two time levels in the data. First, the three policy periods that corresponds to the period before the announcement of the national mask policy (prior to August 15), the period between the announcement (August 15) and the onset of the policy (August 22), and the period after the onset. Second, the observations in the data are also nested within days and, therefore the intercepts and slopes are also allowed to vary by day. The results are presented in four models. Model 1 is a demographics-only model, while models 2-4 include the three behavioral correlates in turn. The size of the estimated coefficients reported below reflects the change in mask use corresponding to a standard deviation change (for the continuous predictors) in each of the correlates, respectively. All reported p-values are from two-sided tests.

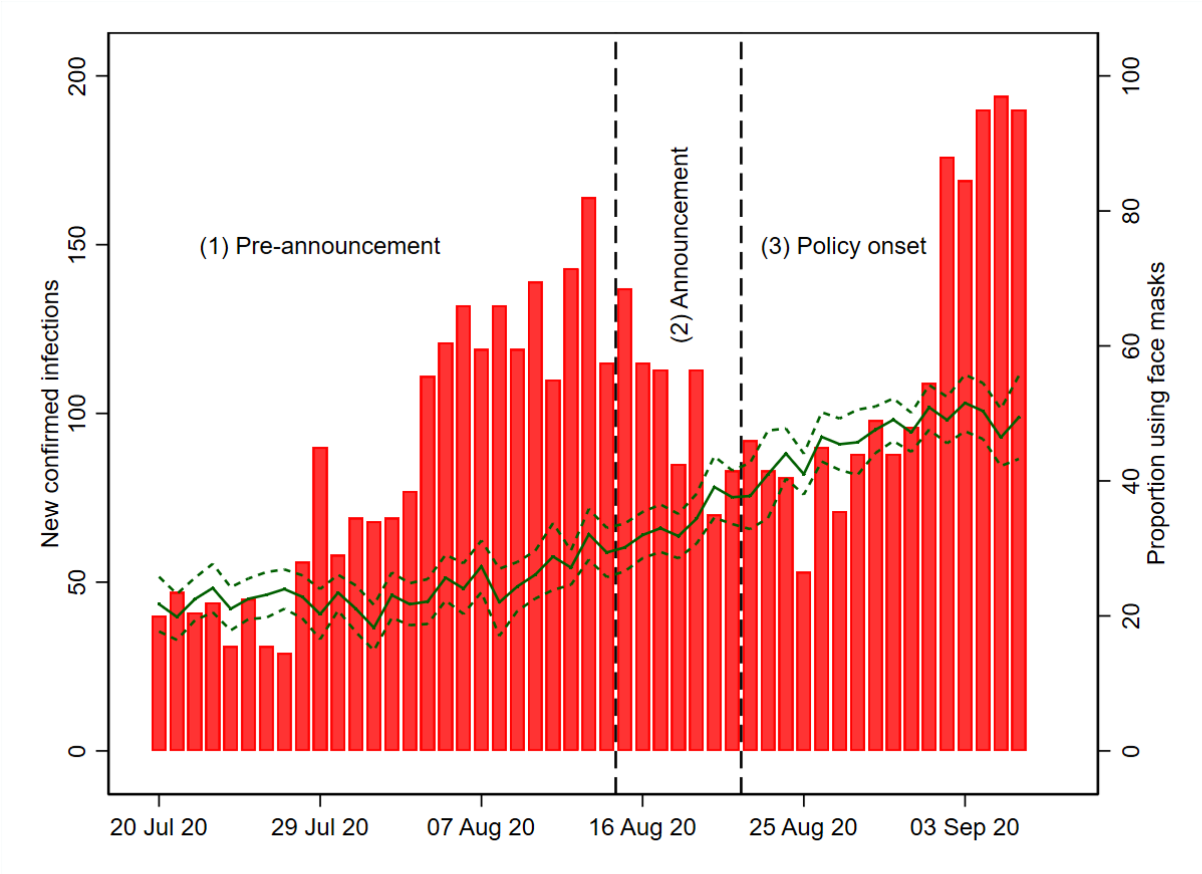
The use of face masks is by no means random. Accordingly, comparisons of protective behavior between people who wear masks and people who do not are biased by selection into each group. The most obvious selection is from reverse causality. For example, people who, even absent face mask use, engage in many contacts can put on a mask to protect themselves against infections. This selection issue can be addressed with an IV approach, where identification relies on the exogenous variation in mask use prompted by the onset of the face mask policy. In particular, we rely on the IV framework developed by Angrist et al. (1999) that allows for heterogeneous treatment effects (see Section S1.5 of the SI for a detailed discussion of this estimator).

Within this framework, we view the change in policy as an exogenous *encouragement* for people to take-up the use of masks. This means that we can define four types of people, i.e., “compliers”, “always-takers”, “never-takers”, and “defiers”. The IV strategy addresses noncompliance, pertaining to “always- and never-taking”, by scaling the so-called intention-to-treat (ITT) effect—i.e., the (covariate-adjusted) difference in outcomes between people before and after the mask policy—by the fraction of compliers (i.e., the so-called first-stage) to isolate the local average treatment effect (LATE) of mask use among *compliers* (Angrist et al., 1999).

This strategy makes three identifying assumptions. First, that defiers are absent, i.e., that no one who would wear masks in the absence of a policy refuses to do so because of the policy. Second, it assumes a strong first-stage, i.e., that the instrument significantly increases the use of face masks. Here, we rely on the strongest available instrument as our main instrument: The *onset* of the face mask policy (see Figure 1). Furthermore, our benchmark sample includes observations ±14 days of the policy threshold, yielding a strong first-stage with an F-statistic of 512. In addition, as discussed below, we show that results are robust to varying the width of this estimate window. Third, the IV estimator assumes that the *potential* use of masks and the *potential* protective behavior outcomes are independent from instrument assignment, implying that the instrument can have no effect on protective behaviors except through its effect on mask use (i.e., the exclusion restriction). In this regard, the key concern is whether the severity of the SARS-CoV-2 epidemic provides an alternative path between the instrument and the protective behaviors. Hence, the face mask policy was changed in response to increases in the incidence rate and the epidemic development might simultaneously be expected to have independent effects on the protective behaviors.

To control against this bias, we take three steps. First, Figure 1 makes it clear that the epidemic develops smoothly over the face mask policy threshold, implying that the *timing* of the instrument is exogenous to the incidence rate. As we narrow the width of the estimation window, we accordingly eliminate biases from differences in epidemic severity. We exploit this to show that our benchmark results are essentially identical when zooming in on the threshold. Second, we include municipality of residence as a covariate in the estimations to match participants who experience similar exposure to (local) incidence rates. Finally, the psychological effects of the epidemic development will take effect through feelings of threat. We therefore including threat appraisal as a covariate (see Table S.3 in the for measurement details). This inclusion also controls for biases that may emerge if the face mask policy itself send a signal of increased threat, which could affect protective behaviors beyond mask use.

Figure 1: Analytical IV-setup



Note: Red bars are confirmed cases. Green solid line is the development in mask use over time (dashed green lines are confidence intervals). Dashed vertical lines the onset and announcement thresholds, respectively.

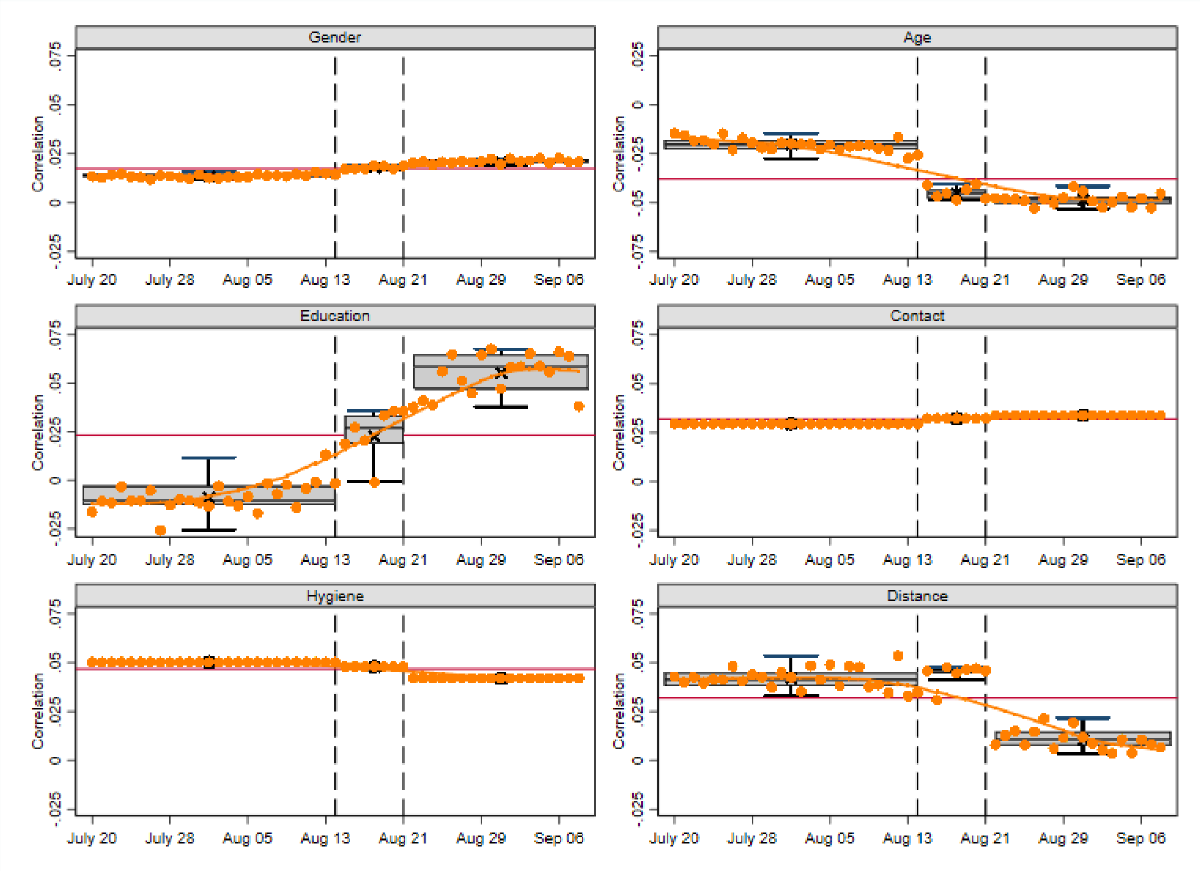
Results

Using the multilevel strategy, Figure 2 displays the developments in how mask usage correlate with each of the other protective behaviors at the individual level (Table Table S.4 in the SI reports the supporting regression table). If correlations are time-invariant, the total correlations (orange filled circles) will fluctuate around the red horizontal lines that display the overall estimates across time. If the correlations shift, the lowess curves (solid orange lines) that display the trends in the total correlations should systematically slope up- or downwards. If such shifts are abrupt, the correlations should jump at the policy thresholds (vertical dashed lines). If shifts occur smoothly, we should see a continuous change over these thresholds. Section S2.1 of the SI provides a detailed discussion of the correlations between mask use and the demographics. Here, we focus on the behavioral correlates.

We observe relatively similar overall correlations between mask use and each type of behavioral correlates. A one standard deviation increase in contacts is associated with 3 percentage points increase in the likelihood of wearing a mask ($\beta_{contact}$ = 0.0319, z = 9.66). Identical results are obtained when replacing the continuous contact measure with a dummy, indicating whether people had any contact or not (see Figure S.3 in the SI). A one standard deviation increase in the attention to hygiene is associated with 4.5 percentage points increase in mask use ($\beta_{hygiene}$ = 0.0467, z = 11.66). A one standard deviation increase in the attention to keeping a distance is associated with 3 percentage points increase in mask use ($\beta_{distance}$ = 0.0319, z = 3.24). While the contact and hygiene correlations are stable over time, the correlation between using masks and distance attention decreases abruptly with the mask policy onset, where the estimated correlation drops from 0.05 to zero.

The positive overall correlations between mask use and attention to hygiene and distancing speak against widespread risk-compensation. Yet, the data also demonstrates that face mask users report more infection-relevant contacts and that the association with distance attention decrease to zero after policy onset. These latter findings may be consistent with the perspective that mask use elicits a false sense of security that motivates people to engage in contacts and attend less to distancing. Alternatively, the correlation may demonstrate that people use face masks as intended: When they cannot avoid contact and keep the advised distance, they wear masks as a precautionary measure. Ultimately, the question of risk-compensation depends on the causal direction in the estimated correlations above.

Figure 2: Behavioral and demographic correlates of mask use



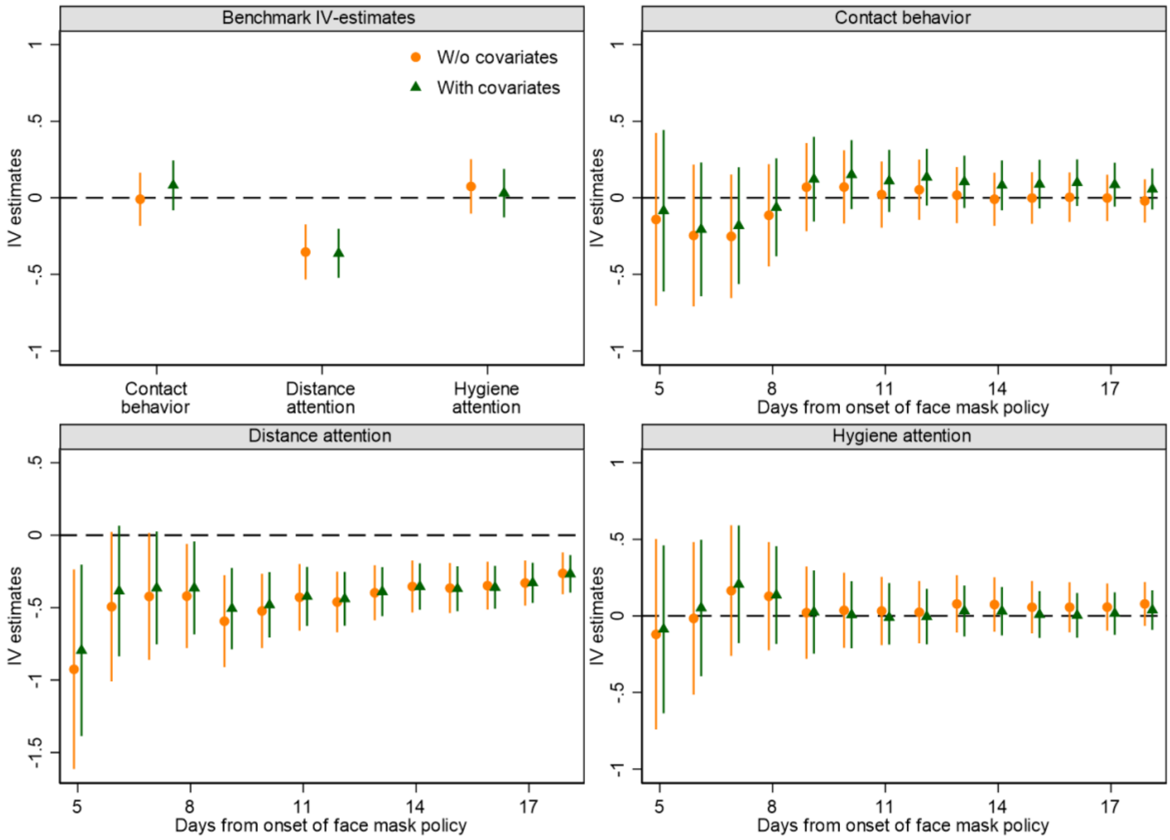
Note: The red horizontal lines indicate the *overall* associations between mask use and each of the correlates. The orange filled circles are the *total* correlations that combine the overall and random correlation parameters to test whether the associations vary over time. The solid orange line is a lowess smoother that describes the trend in the total correlations. The boxes show the distribution of correlations within each policy period (horizontal bars are the lower quartiles, medians, and upper quartiles; black Xs' display the means; and whiskers are 1.5 interquartile range from the quartiles). When estimating the correlations between the behavioral variables and mask use, we include the demographics in the fixed part of the multilevel regression models.

To evaluate the causal impact of face mask use on protective behaviors, Figure 4 presents the results from the IV strategy. The upper-left panel displays the benchmark estimates (Table S.5 in the SI reports the supporting regression table). The benchmark estimates without covariates (orange filled circles) show that the effect of mask use on the number of infection-relevant contacts is essentially zero ($\beta_{contact}$ = -0.0091, z = -0.10). Similarly, mask use has no effect on hygiene attention ($\beta_{hygiene}$ = 0.0730, z = 0.82). To the contrary, mask use has a relatively marked effect on distance attention such that mask users are 0.35 standard deviation less attentive to distancing compared to non-mask users ($\beta_{distance}$ = -0.3539, z = -3.86). If mask use is as good as random among compliers, including or excluding covariates should not substantially change the effect estimates because all covariates (including those unobserved) are well-balanced by design. Consistent with this, the estimates remain virtually unchanged when including covariates (green filled triangles), corroborating the identification strategy.

The upper-right and lower panels show how the effect estimates vary as the width of the estimation window is changed. If mask use is as good as random, the effect estimates will remain stable as the bandwidth is limited and biases from differences in epidemic severity are eliminated. Altogether, the panels display a high degree of stability in the estimates. On distance attention, we see a consistent estimate of about -0.35 or smaller for the effect of mask use on distance attention. On contact behavior and hygiene attention, respectively, the estimates remain small and insignificant as we vary the bandwidth.

In the SI, we report a series of sensitivity tests to probe the robustness of the IV findings. First, we treat mask use as a continuous treatment rather than as an indicator, essentially producing the same results (see Figure S.4). Second, rather than using the policy onset as an instrument, we use the *announcement* of the policy to instrument mask use. Although this increases the variability of the estimated effects, the effect estimates themselves remain remarkably similar to the above estimates (see Figure S.5). Third, we model contact behavior as a count variable rather than a continuous outcome, producing results that are more or less identical to those above (see Figure S.6). Fourth, we also model contact behavior using a dummy that indicates whether the participant had any infection-relevant contacts or not (see Figure S.7).

Figure 3: Estimated effects of mask use on protective behaviors



Note: IV estimates without (orange filled circles) and with covariates (green filled triangles). 95 % confidence intervals. Robust standard errors. Upper-left panel: benchmark estimates include observations ± 14 days of the policy thresholds (first-stage F-statistic = 512). N = 18,377. Remaining panels display effect estimates as we vary the estimation window. We limit the bandwidth of the estimation down to ± 5 days, which is the threshold for preserving a strong first-stage, defined by a critical F-value corresponding to τ = 10% and α = 5%. Covariates: municipality of residence, threat appraisal, sex, age, and education. Effect estimates should be interpreted in standard deviation changes in the protective behavior measures.

For additional interpretive leverage, we replicated the benchmark results while using each individual sub measure in the contact behavior, distance, and hygiene attention scales as separate outcomes (see Figures S.8-S.10 in the SI). For contact behavior and hygiene attention, effects are substantively similar across all sub measures. For distance attention, the negative effects are driven by two specific measures that ask participants to what extent they yesterday were aware of minimizing visitingplaces and activities where "many people typically are going" and "where you have contact to other people", respectively. Consistent with a risk-compensation perspective, this suggests that the adoption of mandatory mask policies specifically motivate people to seek out those settings in which masks are to be used: Crowded public settings where distancing is difficult.

Discussion

Does face mask use facilitate a false feeling of safety that decreases the observation of other key protective advice, so-called risk compensation? Using daily national representative surveys of protective behavior in Denmark as the country adopted a policy of mandatory face mask use in public transportation, we demonstrate that mask use correlates positively with attention to distancing as well as attention to hygienic behavior. At the same time, mask-users also report more infection-relevant contacts compared to non-mask users. While the former findings speak against the risk-compensation hypothesis, the latter may be interpreted in two ways. On the one hand, it may be seen as consistent with the perspective that mask use creates a false sense of security that in turn makes people more likely to engage in contacts. Alternatively, it might show that use masks as intended. Rather than engaging in risk compensating behavior, they wear masks as a precautionary measure when they cannot avoid contact and keep the advised distance.

The question of risk-compensation ultimately depends on the causal direction in these correlations. To gauge this question, we utilized an IV strategy that exploits the changes to Danish face mask policy. The findings from these analyses show that face mask use does not increase the number of infection-relevant contacts and does not decrease hygienic attention. At the same time, face mask use elicits a relatively marked decrease in the attention to distancing by about 0.35 of a standard deviation. This latter effect is driven by decreases in respondents' attention to avoiding places and activities that involves many people.

Overall, these findings suggest that in a population without prior experience with the use of face masks, the onset of a mandatory policy of face mask use during the SARS-CoV-

2 pandemic elicited a narrow form of risk-compensation. Specifically, people decreased their attention to the avoidance of settings involving many individuals, i.e., the specific settings in which masks are used for additional protection. We found no evidence for broader forms of risk-compensation such that face mask use induced more risky behavior in domains beyond their usage such as attention to hygiene or close contacts with, e.g., family and friends.

Importantly, these findings do not suggest that face masks are not an effective tool to hinder the spread of infections during the SARS-CoV-2 pandemic. However, they do suggest that the effectiveness of face masks can be increased if the onset of mandatory policies of face mask are combined with clear communications from health authorities that remind people about the importance of physical distancing and that face masks are not a substitute for such distancing.

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Supplementary Information

Contents

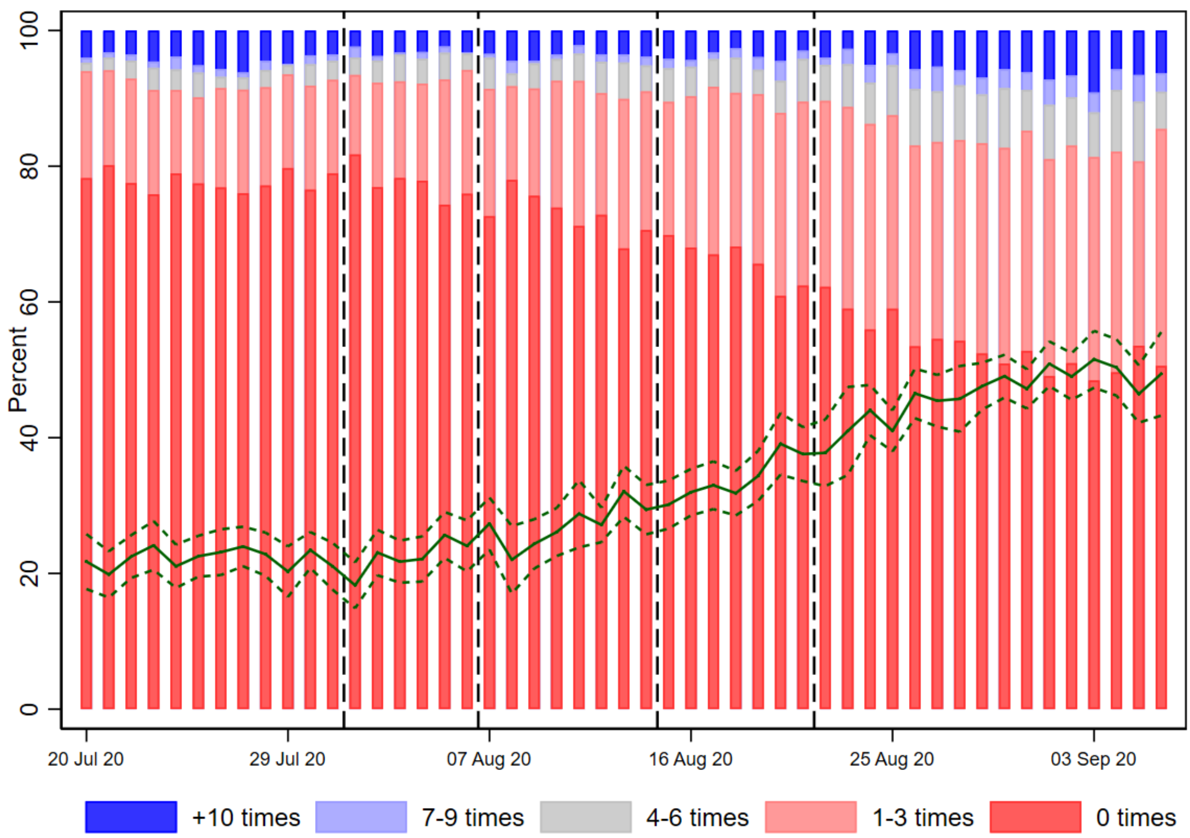
S1 Methods and materials

In this section of the SI, we provide supplementary information pertaining to the discussions in the main manuscript about the methods and materials. First, we show the development in face mask use over time. Second, we provide an overview of the data collection. Third, a more detailed overview of response rates, by group. Fourth, we supply the overview of the covariates in the study. Fifth, and finally, we discuss in more detail the IV identification strategy.

S1.1 Policy development

The vertical dashed lines in Figure S.1 indicate the announcement of the national face mask policy (August 15) and the onset (August 22), respectively. The figure shows a marked change in the proportion of participants who report that they have used a face mask over time. Focusing on the development in the indicator for face mask use, we see a relatively stable proportion of about 20 percent who report that they use a face mask prior to the policy announcement on August 15. After the announcement, this proportion increases continuously over time and by in the beginning of September about 50 percent in our samples report that they have used a face mask. Moving to the development in the full distribution (the stacked bars), we see that the increase in face mask use over time is primarily driven by respondents who report that they have used a face mask 1-3 or 4-6 times within the last week.

Figure S.1. Development in the use of face masks among Danes



Note: Stacked bars show the development in the distribution of face mask use. Solid green line is the development in the indicator for mask use. Dashed green lines are 95 % confidence intervals.

S1.2 Overview of data collection

Table S.1: Overview of data collection

Date	7/20	7/21	7/22	7/23	7/24	7/25	7/26	7/27	7/28	7/29	7/30	7/31	8/1	8/2
N	665	537	545	443	488	578	487	675	527	354	781	417	391	470
Date	8/3	8/4	8/5	8/6	8/7	8/8	8/9	8/10	8/11	8/12	8/13	8/14	8/15	8/16
N	545	481	491	397	421	210	447	466	268	1,188	606	606	652	717
Date	8/17	8/18	8/19	8/20	8/21	8/22	8/23	8/24	8/25	8/26	8/27	8/28	8/29	8/30
N	692	778	647	449	575	379	224	694	1,025	732	669	412	814	970
Date	8/31	9/1	9/2	9/3	9/4	9/5	9/6	9/7	9/8					
N	1,151	895	817	552	566	538	257	508	630					

S1.3 Response rates

Table S.2: Detailed overview of response rates, by group

Sex	**Age**	**Invites**	**Complete**	**Response rates**
Male	18-29	16137	5036	31.2
Male	30-39	8739	3611	41.3
Male	40-49	11290	4328	38.3
Male	50-59	12322	5803	47.1
Male	60-69	7226	4106	56.8
Male	70+	8342	4628	55.5
Female	18-29	11532	5366	46.5
Female	30-39	6167	3461	56.1
Female	40-49	10377	4957	47.8
Female	50-59	10581	5961	56.3
Female	60-69	6886	4240	61.6
Female	70+	10494	5524	52.6

Note: Cell entries delivered by Kantar Gallup on September 9.

S1.4 Measurements of covariates

Table S.3: Covariates in the study

	Questions	Values
Age	How old are you?	Numeric
Gender	Are you?	0 = Male 1 = Female
Education	What is your highest completed education? Holds information corresponding to Danish applicable categories: 1. Elementary school 2. High school 3. Vocational training 4. Short higher education 5. Medium higher education 6. Bachelor 7. Long higher education 8. PhD We translated these into the internationally comparable ISCED-scale and divide into two categories.	0 = non-tertiary education 1 = tertiary education
Threat appraisal	To what degree do you feel, that • You are exposed regarding the Corona virus? • The Corona virus is a threat to Danish society? We add these two questions together into our threat appraisal covariate.	1. Not at all 2. 3. 4. 5. 6. 7. To a high degree 8. Don’t know
Municipality	Administrative information supplied by Danish statistics about each participants municipality of residence	

Note: Scale reliability is measured by α. NA=not applicable.

S1.5 The IV Identification strategy

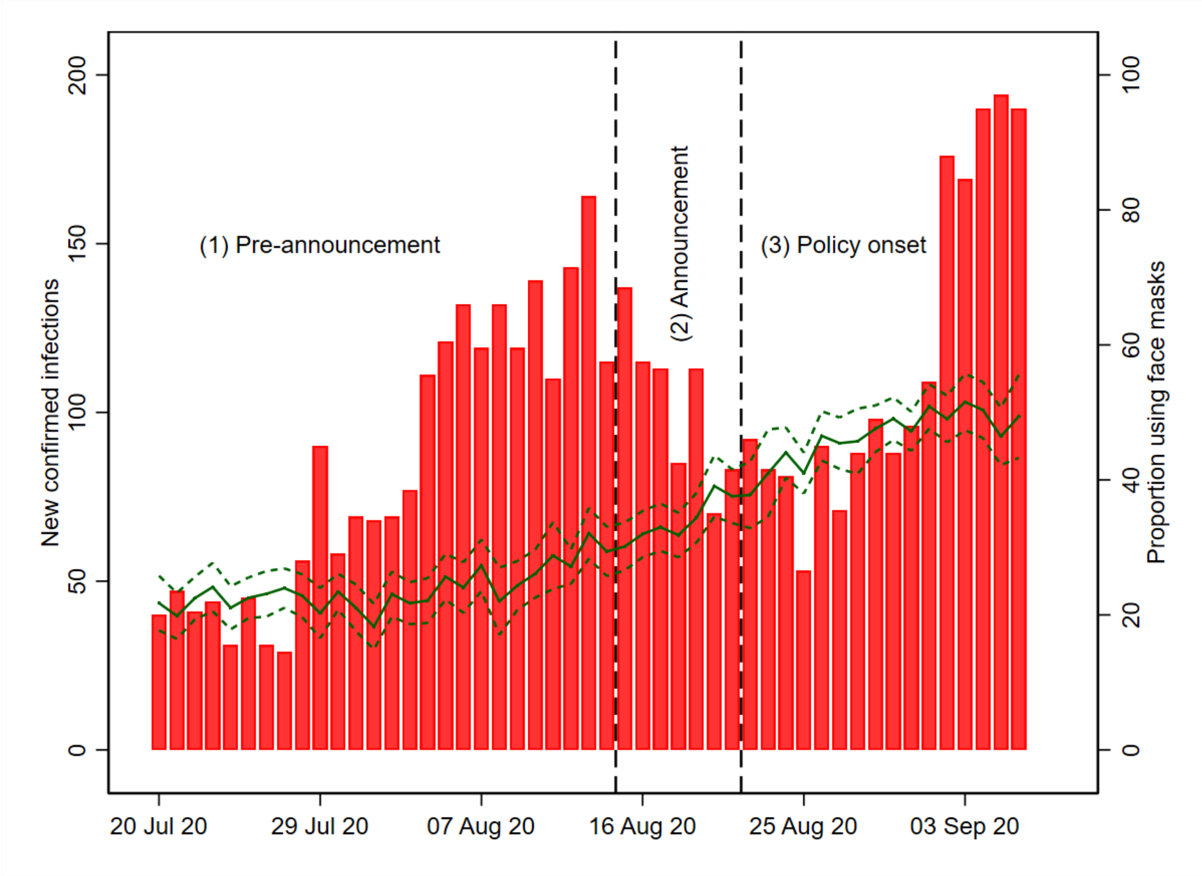
We address the selection using an IV approach as described in the manuscript. Causal identification relies on the exogenous variation in mask use prompted by the change in face mask policy. In particular, we rely on the IV framework developed by Angrist et al. (1999) that allows for heterogeneous treatment effects. We view the change in policy as an exogenous encouragement for people to take up the use of masks. In light of this framework, we can define four types of people. “Compliers” are people who comply with the encouragement. In other words, people who did not use mask prior to the change in policy, but take up mask use after the policy change. “Always-takers” are people who always use masks regardless of the policy. “Never-takers” are people who never wear masks regardless of the policy. Finally, “defiers” are people who refuse to wear masks because of the policy (or insist to wear mask in the absence of policy). The IV strategy addresses noncompliance by scaling the so-called intention-to-treat (ITT) effect—i.e., the (covariate-adjusted) difference in outcomes between people before and after the mandatory mask policy—by the fraction of compliers (the so-called compliance rate) to isolate the local average treatment effect (LATE) of mask use among compliers (Angrist et al., 1999).

The IV strategy makes three identifying assumptions. *First*, it assumes a first-stage. That is, the instrument should significantly increase the use of face masks. We potentially have two different instruments. The first instrument being the announcement of the policy. The second, being the onset. In the manuscript, we use the onset as our benchmark, but Figure S.5 in this appendix shows that results are similar if replacing the onset instrument with the announcement. As discussed in the manuscript, we focus our benchmark estimates on a sample that includes observations ±14 days of the policy threshold, yielding a strong first-stage with an F-statistic of 512.

Figure 1 of the manuscript and Figure S.2 display the analytical setup. We use the indicator of mask policy onset to instrument actual mask use. That is, we estimate the difference in protective behavior outcomes prior and after the mask policy onset (i.e., the ITT) and scale it by the compliance rate (i.e., the first-stage). This estimate, *second* and most crucially, assumes that the *potential* use of masks and the *potential* protective behavior outcomes are independent from instrument assignment, implying that the instrument can have no effect on protective behaviors except through its effect on mask use (i.e., the exclusion restriction).

In this regard, a relevant concern is whether the severity of the SARS-CoV-2 epidemic provides an alternative path between the instrument and the protective behaviors. Hence, the face mask policy was changed in response to increases in the incidence rate and the epidemic development might simultaneously be expected to have independent effects on the protective behaviors. However, from Figure S.2 it is clear that the epidemic develops smoothly over the face mask policy threshold, implying that the *timing* of the instrument is exogenous to the incidence rate. As we narrow the width of the estimation window, we accordingly eliminate biases from differences in epidemic severity. We exploit this to show that our benchmark results are essentially identical when zooming in on the threshold. To provide additionally control against this bias, we also include municipality of residence as a covariate in the estimations to match participants who experience similar exposure to (local) incidence rates. A related concern is that the change in face mask policy can send a signal of increased *threat*, which could affect protective behaviors through a path outside of increased mask use. We close this path by including threat appraisal as a covariate (see Table S.3 above for details of measurement).

Figure S.2: Analytical IV-setup



Note: Red bars are confirmed cases. Green solid line is the development in mask use over time (dashed green lines are confidence intervals). Dashed vertical lines the onset and announcement thresholds, respectively.

Finally, our LATE estimators assume monotonicity. I.e., the absence of "defiers". Most plausibly, this is people who do not use masks because of the face mask policy, but who would wear masks in the absence of a policy. Overall, this problem seems inconceivable (at least at a large enough scale to influence our estimates substantively). One way of empirically assessing the monotonicity assumption is to utilize that the municipality of Aarhus and its neighboring municipalities implemented local face mask restrictions prior to the national restriction on August 7. If defying behavior was an issue (at a large scale), then we would expect a downwards adjustment in mask use among people outside the impacted areas. We do not observe this pattern. Instead, the development in face mask use among people outside the local areas remain very stable across the local intervention threshold, probing the robustness of the assumption.

S2 Supporting results: Correlational findings

In this section, we provide first the supporting regression table for the correlational results in the manuscript. Second, we show that the correlations remain substantively similar when replacing the continuous contact scale with a dummy that indicates whether or not the participant reports any infection-relevant contacts, corroborating the robustness of the results.

S2.1 Supporting regression table and interpretation of the multilevel regression results

Focusing on the demographic correlates, we see that females overall are about 1.5 percentage points more likely to wear masks compared to males (β_{female}= 0.0175, z = 2.77). This correlation varies very little over time. In fact, neither the between or within policy period estimates are significantly different from the overall correlation. Moving to the age correlation, a one standard deviation increase in age is overall associated with about a 4 percentage point decrease in the likelihood of wearing a mask (β_{age}= -0.0378, *z* = -4.53). Here, we see a clear shift over time that occurs abruptly from with the announcement of the mask policy. Hence, in the pre-announcement period there is only a small correlation between age and mask use of about -0.02. However, with the announcement this correlation doubles to about -0.04 and we see a further smooth adjustment down to about -0.05 in the beginning of September. The overall correlation between education and mask use is not statistically distinguishable from zero ($\beta_{education}$= 0.0232, *z* = 1.35), but this reflects a significant amount of variation over time. In particular, we see two periods in the data: before and after the policy announcement. In the pre-announcement period, the correlations are negative, but slopes smoothly upwards. After the announcement, we see a clear jump in the correlations that, then, increases smoothly until the beginning of September, where the better educated are about 7 percentage points more likely to wear face masks compared to the less educated.

Table S.4: Demographic and behavioral correlates of face mask use

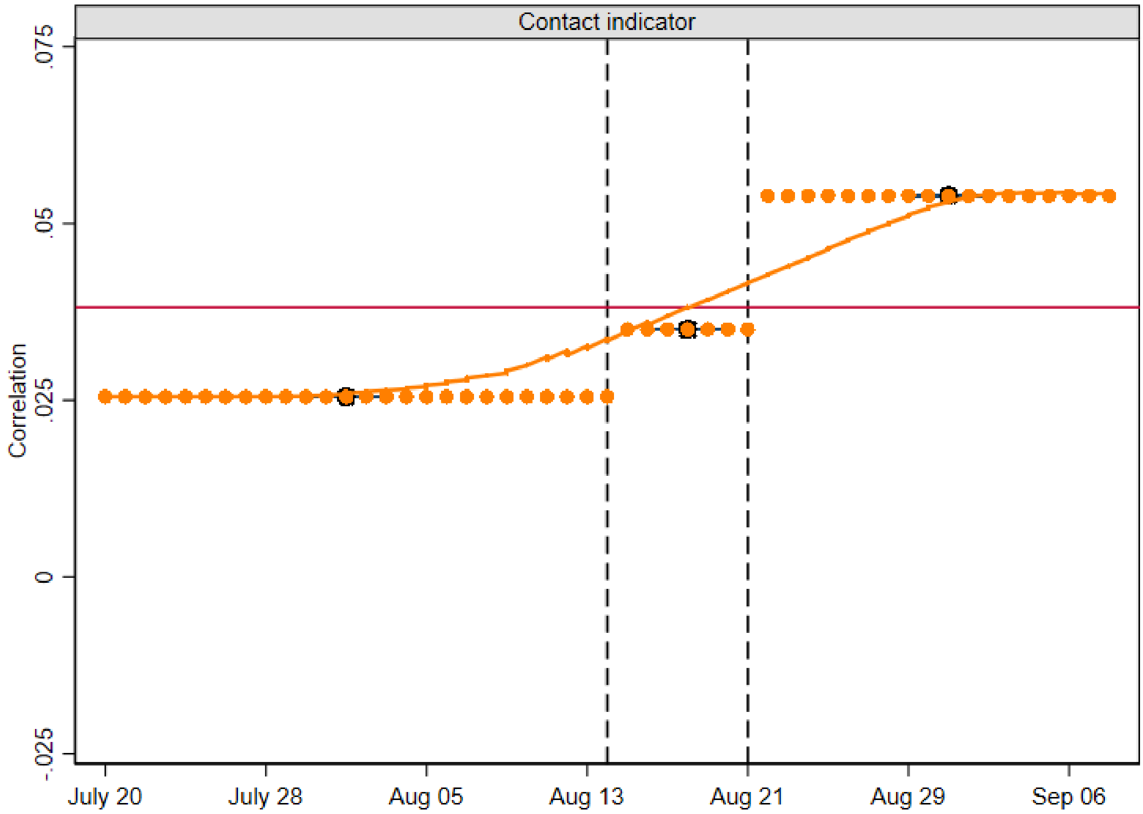
	Model 1	Model 2	Model 3	Model 4
Fixed parameters				
Behavioral				
Contact behavior (1 sd)		0.032*** (0.003)		
Hygiene attention (1 sd)			0.047*** (0.004)	
Distance attention (1 sd)				0.032*** (0.006)
Demographics				
Female	0.018** (0.006)	0. 018** (0.005)	0.001 (0.005)	0.012* (0.007)
Age (1 sd)	-0.038***(0.008)	-0.030*** (0.003)	-0.045*** (0.003)	-0.043***(0.003)
Education (tertiary)	0.023 (0.017)	0.022*** (0.006)	0.025*** (0.005)	0.022*** (0.006)
Constant	0.327*** (0.046)	0.327*** (0.057)	0.333*** (0.056)	0.329*** (0.057)
Random parameters: Policy periods				
Sd (Contact behavior)		0.003 (0.004)		
Sd (Hygiene attention)			0.005 (0.004)	
Sd (Distance attention)				0.016 (0.007)
Sd (Female)	0.006 (0.008)			
Sd (Age)	0.013 (0.006)			
Sd (Education)	0.027 (0.013)			
Sd (constant)	0.080 (0.033)			
Random parameters: Day				
Sd (Contact behavior)		0.000 (0.000)		
Sd (Hygiene attention)			0.000 (0.000)	
Sd (Distance attention)				0.011 (0.004)
Sd (Female)	0.006 (0.018)			
Sd (Age)	0.008 (0.005)			
Sd (Education)	0.019 (0.008)			
Sd (constant)	0.027 (0.005)			
Observations	31,446	31,446	31,441	31,435

Notes: Unstandardized multilevel regression coefficients. Standard errors in parentheses.* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

S2.2 Infection-relevant contacts modeled as an indicator (any contact vs. no contact)

We replace the continuous contact scale used in the main results with a dummy that indicates whether participants had any contacts or not. While the overall correlation is substantively similar to the main results, i.e., an estimate of 0.039 ($z = 3.62$) compared to the estimate in the main results of 0.032 ($z = 9.66$), we see a larger degree of variability in the correlations over time. In particular, we see a clear upwards shift in the correlation associated with the face mask policy onset.

Figure S.3: Any infection relevant contacts vs. no contact



Note: The red horizontal line indicate the *overall* association between mask use and the contact indicator. The orange filled circles are the *total* correlations that combine the overall and random correlation parameters to test whether the associations vary over time. The solid orange line is a lowess smoother that describes the trend in the total correlations.

S3 Supporting results: IV findings

In this section of the SI we present the supporting results for the IV findings. First, we provide the supporting regression table for the benchmark IV estimates. Second, we provide a series of sensitivity analyses that probe the robustness of the IV findings, including (1) displaying the results across the sub measures of each of the protective behavior scales, (2) treating mask use as a continuous treatment, (3) replacing the instrument for the announcement of the face mask policy rather than the onset, (4) modeling the number of infection relevant contacts as a count variable, and (5) modeling contact behavior as a dummy, indicating whether or not the individual had any infection relevant contacts or not.

S3.1 Supporting regression table for the benchmark IV estimates

Table S.5: Benchmark IV estimates, regression table

	Contacts	**Contacts**	**Distance**	**Distance**	**Hygiene**	**Hygiene**
Mask use effect	-0.0091	0.0059	-0.3539***	-.2313**	0.0744	0.0145
	(0.0888)	(0.0847)	(0.0918)	(0.0843)	(0.0906)	(0.0845)
Covariates	×	√	×	√	×	√
First-stage F-stat	512	96	513	96	513	96
Observations	18,377	18,137	18,377	18,137	18,377	18,137

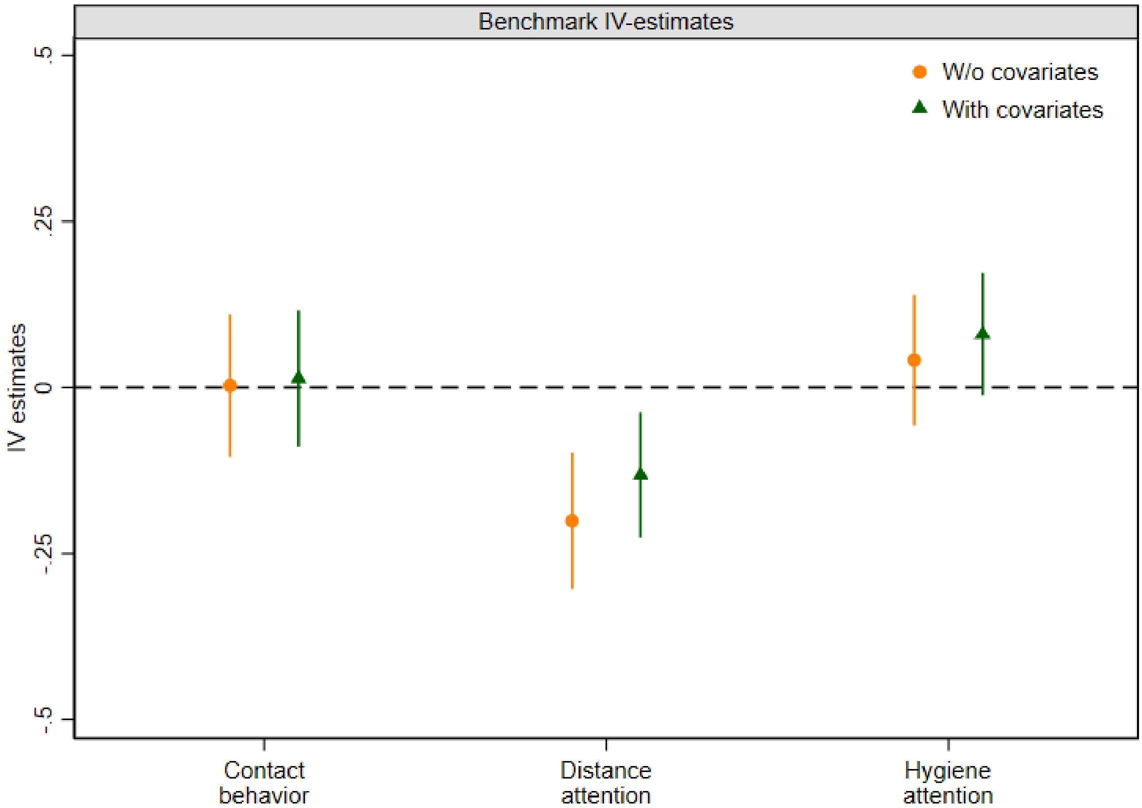
Note: Estimated local average treatment effects among compliers. Robust standard errors in parentheses. Covariates: municipality of residence, threat appraisal, sex, age, and education. Estimates should be interpreted in standard deviation changes in the protective behavior outcomes.

S3.2 Robustness of IV findings

S3.2.2 Mask use as continuous treatment

Figure S.4 show that the main results are essential identical when treating mask use as a continuous treatment rather than a dummy, indicating whether or not the participant has used a mask within the last week.

Figure S.4: Benchmark estimates, mask use treated as a continuous treatment

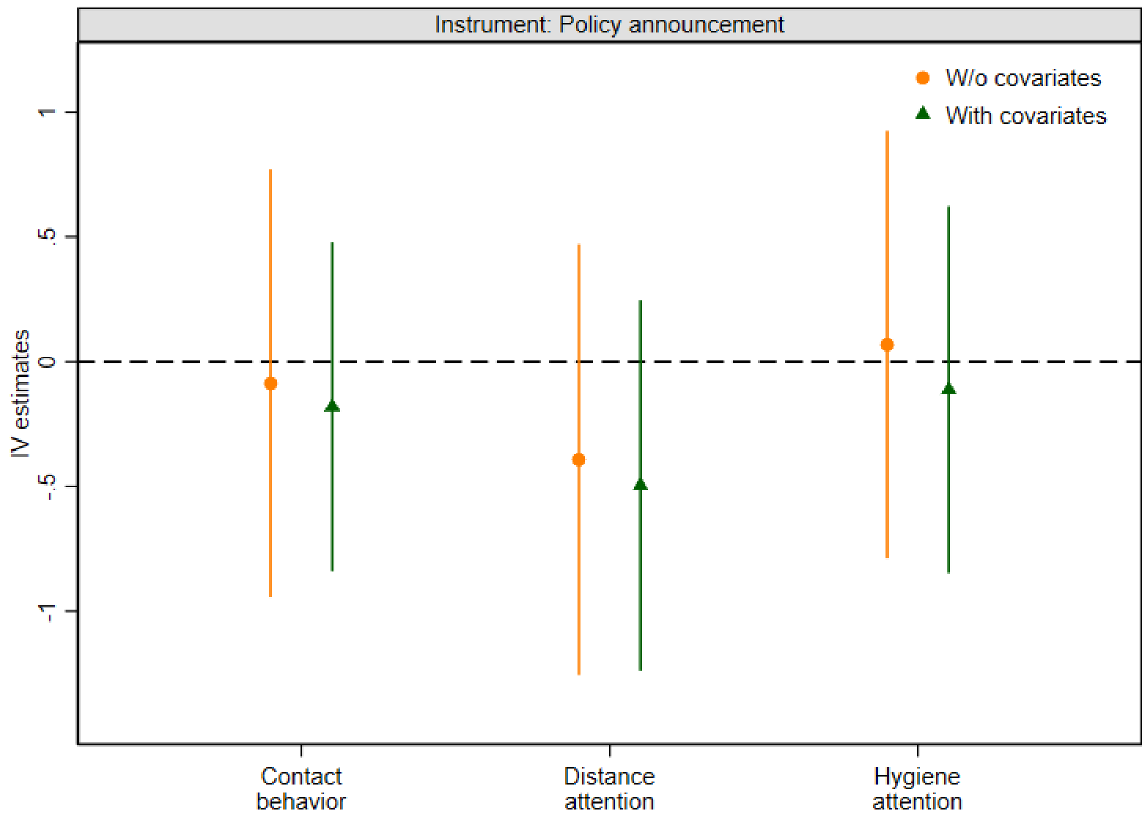


Note: IV estimates without (orange filled circles) and with covariates (green filled triangles). 95 % confidence intervals. Robust standard errors. Estimates include observations ± 14 days of the policy thresholds (first-stage F-statistic = 512). N = 18,377. %. Covariates: municipality of residence, threat appraisal, sex, age, and education. Effect estimates should be interpreted in standard deviation changes in the protective behavior measures.

S3.2.3 Announcement as instrument

Figure S.5 shows the estimated effects of mask use when using the *announcement* of the policy as an instrument rather than the policy onset. We see that the effect estimates remain fundamentally unchanged, while the variability of the estimated effects increases. An explanation for this increase in variability is that we limit the width of the estimation window to ± 6 days of the announcement threshold (August 15). The choice of bandwidth is essentially a bias-variance-tradeoff. We select the bandwidth that limits bias as much as possible while still preserving a strong first-stage, defined by a critical F-value corresponding to τ = 10% and α = 5%. Hence, we are limited in terms of how wide we can make the width of the estimation window—at least if we want to keep the bandwidth symmetric—without including observations that are affected by the onset of the policy (August 22).

Figure S.5: Benchmark estimates, instrument = announcement of the mask policy

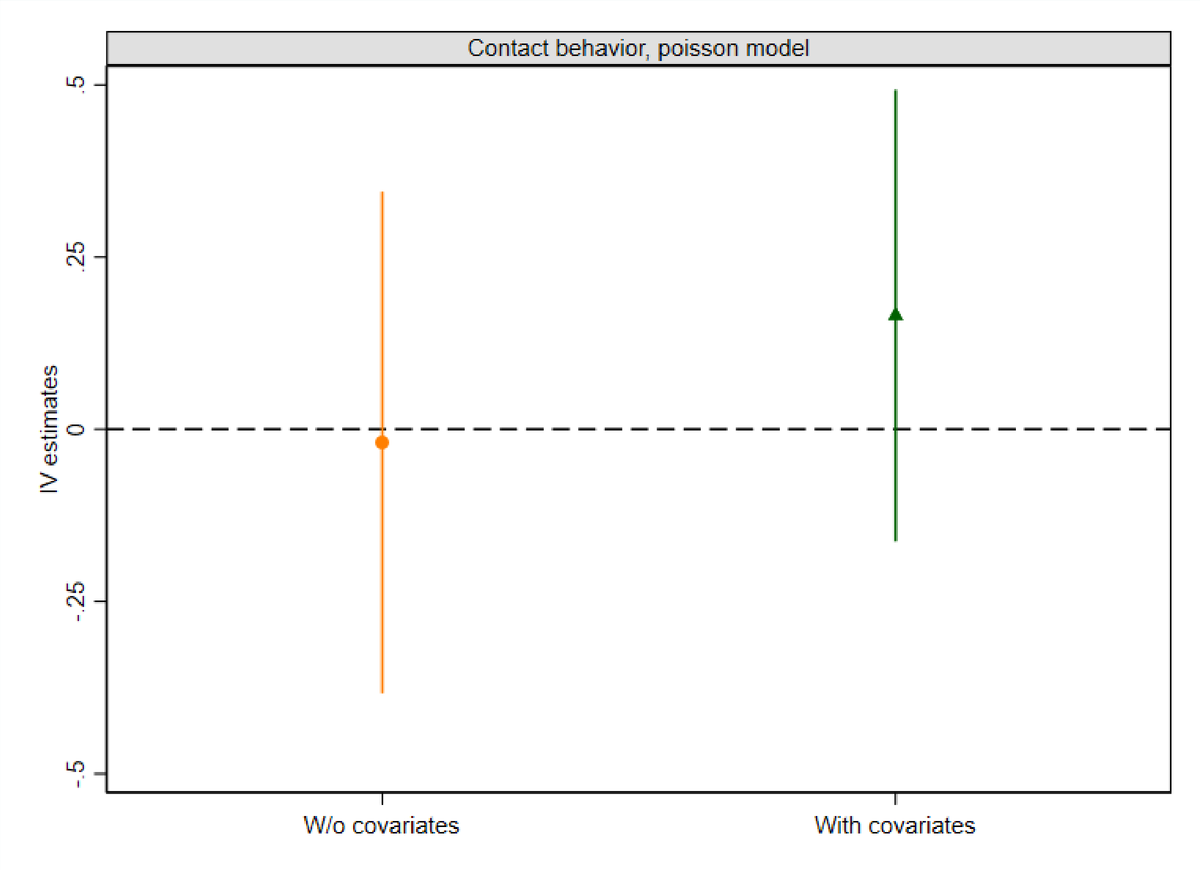


Note: IV estimates without (orange filled circles) and with covariates (green filled triangles). 95 % confidence intervals. Robust standard errors. Estimates include observations ± 6 days of the policy announcement (first-stage F-statistic = 25). N = 7,724. %. Covariates: municipality of residence, threat appraisal, sex, age, and education. Effect estimates should be interpreted in standard deviation changes in the protective behavior measures.

S3.2.4 Contact behavior modeled as count variable

Figure S.6 shows the estimated effects of mask use on the number of infection-relevant contacts, when modeled as a count using a IV gmm estimator. As we see, the findings are substantively similar to the main results.

Figure S.6: Contact benchmark estimates, modeled as a count variable

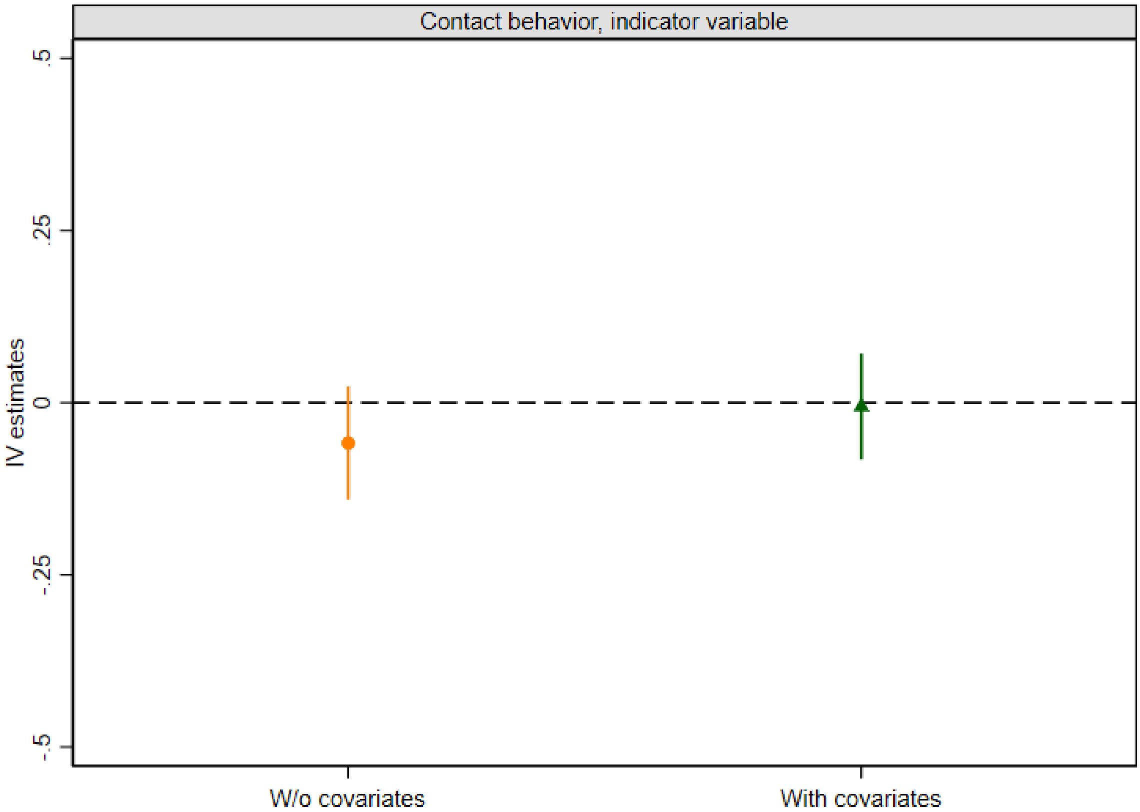


Note: IV estimates without (orange filled circles) and with covariates (green filled triangles). 95 % confidence intervals. Robust standard errors. Estimates include observations ± 14 days of the policy thresholds (first-stage F-statistic = 512). N = 18,377. Covariates: municipality of residence, threat appraisal, sex, age, and education.

S3.2.5 Contact behavior modeled as an indicator

Figure S.7 substitutes the continuous contact scale for a dummy that indicates whether the participant had any infection-relevant contacts or not. Conclusions remain unchanged.

Figure S.7: Benchmark estimates, mask use treated as a continuous treatment

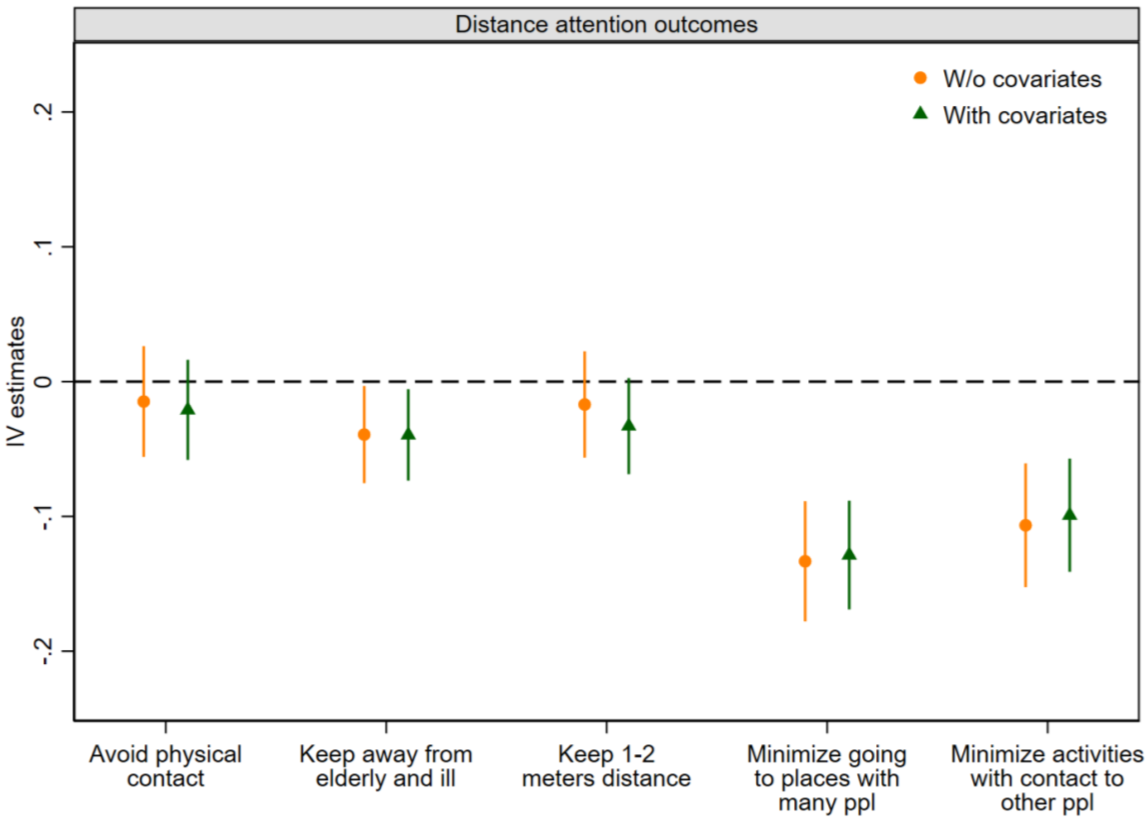


Note: IV estimates without (orange filled circles) and with covariates (green filled triangles). 95 % confidence intervals. Robust standard errors. Estimates include observations ± 14 days of the policy thresholds (first-stage F-statistic = 512). N = 18,377. %. Covariates: municipality of residence, threat appraisal, sex, age, and education.

S3.2.5 IV results on sub measures of each protective behavior scale

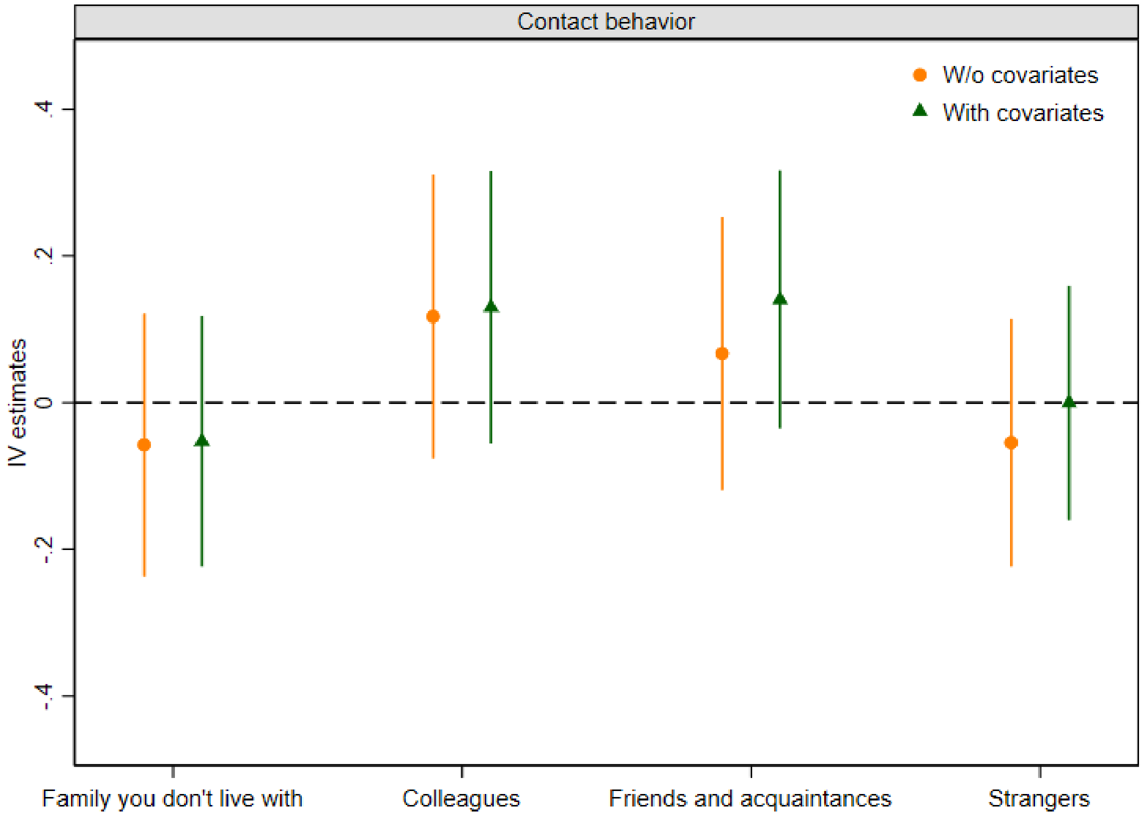
Figures S.8-S.10 replicate the benchmark results of the manuscript while using each individual sub measure of the protective behavior scales as separate outcomes. Figure S.8 show that the estimated negative effects on the distance attention scale is driven by the two sub measures that ask participants to what extent they yesterday were aware of: (1) minimize going to places where many people typically are going and (2) minimize activities where you have contact to other people. For contact behavior and hygiene attention, Figures S.9 and S.10 show that effects are substantively similar across the sub measures.

Figure S.8: Benchmark effect estimates on the sub measures of the distance attention scale



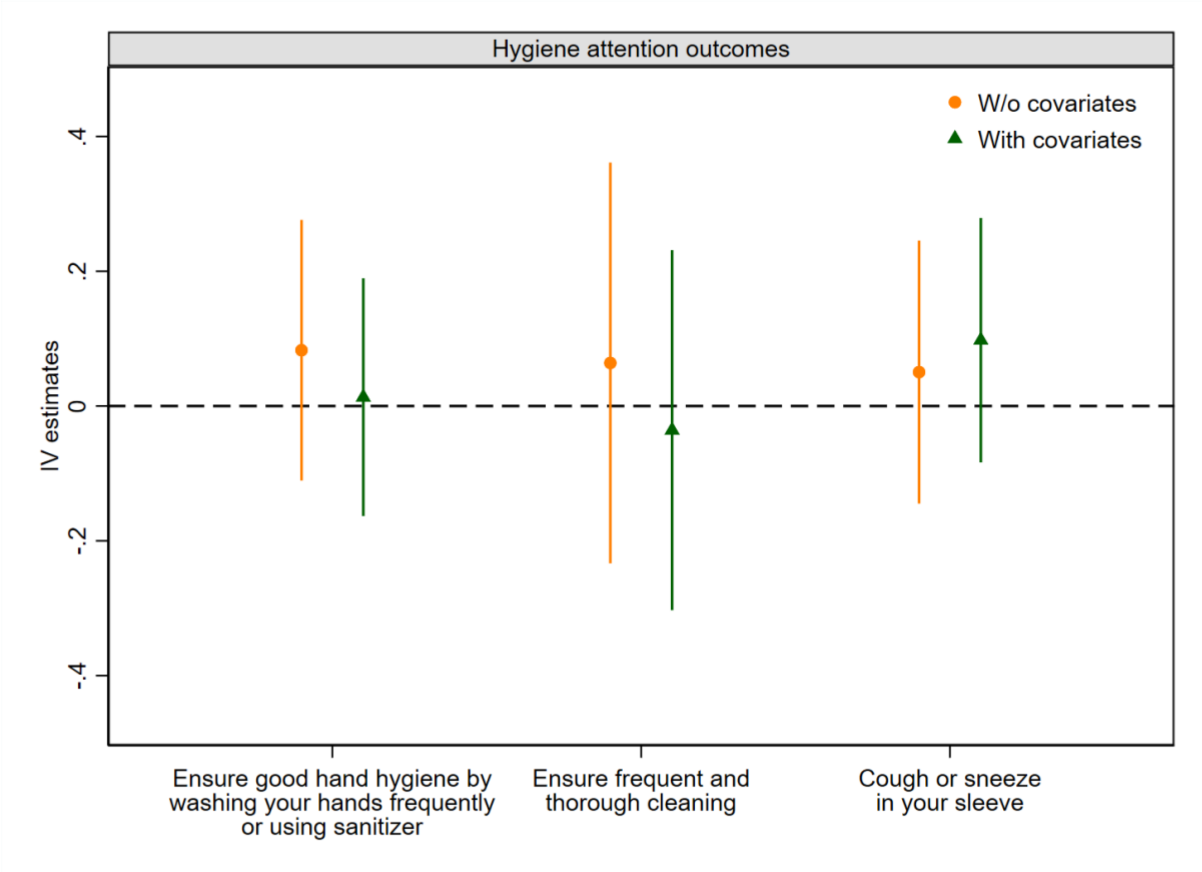
Note: IV estimates without (orange filled circles) and with covariates (green filled triangles). 95 % confidence intervals. Robust standard errors. Estimates include observations ± 14 days of the policy thresholds (first-stage F-statistic = 512). N = 18,377. The outcomes are scaled from 0-1 and the effect estimates should accordingly be interpreted in percentage point changes. Covariates: municipality of residence, threat appraisal, sex, age, and education.

Figure S.9: Benchmark effect estimates on the sub measures of the contact scale



Note: IV estimates without (orange filled circles) and with covariates (green filled triangles). 95 % confidence intervals. Robust standard errors. Estimates include observations ± 14 days of the policy thresholds (first-stage F-statistic = 512). N = 18,377. The outcomes are scaled from 0-1 and the effect estimates should accordingly be interpreted in percentage point changes. Covariates: municipality of residence, threat appraisal, sex, age, and education.

Figure S.10: Benchmark effect estimates on the sub measures of the hygiene attention scale



Note: IV estimates without (orange filled circles) and with covariates (green filled triangles). 95 % confidence intervals. Robust standard errors. Estimates include observations ± 14 days of the policy thresholds (first-stage F-statistic = 512). N = 18,377. The outcomes are scaled from 0-1 and the effect estimates should accordingly be interpreted in percentage point changes. Covariates: municipality of residence, threat appraisal, sex, age, and education.