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Willingness to Use an Approved COVID-19 Vaccine: Cross-National Evidence on Levels and Individual-Level Predictors

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Abstract

Objectives

The management of the COVID-19 pandemic critically hinges on the approval of safe and effective vaccines but, equally importantly, on high willingness among lay people to use vaccines when approved. To facilitate vaccination willingness via effective health communication, it is key to understand both levels of skepticism towards an approved COVID-19 vaccine and the demographic, psychological and political sources of this skepticism. To this end, we examine the levels and predictors of willingness to use an approved COVID-19 vaccine.

Design, setting and participants

We examine the levels and predictors of willingness to use an approved COVID-19 vaccine in large, representative surveys from eight Western democracies that differ both politically and in terms of the severity of the pandemic: Denmark, France, Germany, Hungary, Sweden, Italy, United Kingdom, and United States (total N = 9,889). We fielded quota-sampled surveys in these countries using online panels. Survey respondents were quota sampled to match the population margins on age, gender, and geographic location for each of the eight countries in our study.

Main outcome measures

The main outcome of the study is vaccination willingness for an approved COVID-19 vaccine.

Results

The data reveal large variation in vaccination willingness, both across and within countries ranging from 79 % in Denmark to 38 % in Hungary. Thus, most national levels fall below current best estimates for the required threshold for reaching herd immunity. Across national and demographic groups, the analyses demonstrate that a lack of vaccination willingness is associated with low levels of trust in authorities, conspiracy-related beliefs and a lack of

concern about COVID-19. These factors also account for cross-national levels in vaccination willingness.

Conclusion

Our results reveals concerning levels of vaccination willingness and suggest that best communication target is the consequences of infections for the self and close others.

Strengths and limitations of this study

- Large samples that are reflective of the populations of interest.
- Cross-national data that allows to examine the generalizability of findings and the factors underlying cross-national differences.
- An broad-based assessment of potential correlates of vaccination willingness, including both demographics, political and COVID-specific factors.
- Observational data which limits causal traction.

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Background

A vaccine against COVID-19 is a "vital tool" in the management of the current pandemic and will help societies world-wide to return to normal.[1] Accordingly, researchers, authorities and industry have invested extraordinary amounts of resources into vaccine development with unprecedented speed and, currently, about 40 vaccine candidates are in the process of or have already recruited human participants for medical trials.[2]

Yet, even when an approved vaccine is widely available, societies across the world will face another challenge: Vaccine skepticism. Researchers currently estimate that up to 82 percent of the population of any given country may need to be vaccinated in order to reach herd immunity.[3-4] However, experts acknowledge that there is an increasing trend toward vaccine hesitancy.[5] This has been the case for many non-COVID-19 vaccine programs, and is also likely to pose a challenge for COVID-19 vaccines.[6-7] Consistent with this, initial cross-national survey evidence suggests that substantially fewer people worldwide are willing to get vaccinated than would be necessary; and that some countries – e.g. Russia, Poland and France – face strikingly high levels of skepticism.[8] Thus, a key challenge for the management of pandemic is for health authorities (and, potentially, other actors) across the world to encourage people to accept an approved COVID-19 vaccine through careful approval procedures and effective health communication. This latter challenge emphasizes the importance of understanding why people are hesitant about taking a future vaccine. Such knowledge will be crucial for optimizing communication about an approved vaccine in a way that will increase vaccination willingness.

In this manuscript, we present a descriptive analysis of the willingness to receive a future approved COVID-19 vaccine across eight Western democracies. Furthermore, we investigate individual-level predictors of vaccination willingness. The results demonstrate that for most of the countries in our sample, people are only moderately willing to receive a vaccine. Furthermore, vaccine skepticism is pronounced with more than 10 percent in six out of eight countries saying that they will refuse a future COVID-19 vaccine. The analyses of the individual-level predictors demonstrate that this vaccine skepticism is fueled by three factors: (1) *lack of trust* in the national health authorities, (2) *conspiracy-related concerns* about the authorities' handling of the pandemic, and (3) a *lack of concern about the personal consequences* of the corona pandemic. The role of these factors are remarkably constant across countries and demographic groups and additional analyses suggest that they also inform

national-level variation in vaccination willingness. While these results highlight features to emphasize in health communication, they also point to the challenges faced by health agencies across the world: Trust is difficult to establish via short term communication and the existing evidence suggest that the toll of the pandemic so far has eroded rather than increased the public's trust in authorities.[9]

Potential predictors: Who are expected to be willing to get a future approved COVID-19 vaccine?

To understand the individual-level sources of vaccination willingness – and, hence, the potential target of health communication to increase such willingness – we utilize a broad-based approach and assess a multitude of potential sources. On the basis of prior research on attitudes about vaccines in general and COVID-19 vaccines in particular, it is relevant to consider at least five categories of predictors: (1) Background demographics, (2) trust in relevant authorities and groups, (3) disease-specific risk-perceptions, (4) disease-specific attitudes including conspiracy-related attitudes and (5) propensities to engage in other forms of disease-specific protective behavior.

Regarding background demographics, prior studies of vaccine acceptance of a future COVID-19 vaccine have found that males are more likely to accept a potential COVID-19 vaccine [10-12], potentially due to sex-based differences in COVID-19 mortality.[10] Another relevant predictor is age and it seems reasonable that older people would be more willing to receive a vaccine due to a higher risk of a severe infection. This is confirmed by Lazarus et al. (2020)[8] and Hacquin et al. (2020)[12], but neither Dror et al. (2020) nor Wong et al. (2020)[10-11] found any age differences in vaccine acceptance. Prior studies on vaccine hesitancy have also focused on education. Lower education among parents is significantly associated with vaccine refusal for child vaccine programs,[13] and lower education is also associated with general vaccine hesitancy,[14] and COVID-19 vaccine hesitancy.[12] Thus, we include sex, age and education as demographic predictors in our model. As a final background predictor, we also include individual differences in political ideology. In context of the COVID-19 pandemic, prior research found that compliance with health advice may be influenced by political ideology, especially in regions where the pandemic has been the target of political polarization.[15]

Trust is a crucial predictor of vaccine acceptance. Guay et al. (2019), for example, found that distrust in public health authorities is associated with general vaccine hesitancy.[14] This relationship has been well-documented in case of specific vaccine programs too. For example, people who trust the health authorities, doctors and the government were more likely to accept the HPV vaccine.[16] Initial work on COVID-19 vaccines also demonstrates that those who have higher trust in scientists are more willing to get vaccinated.[17] Finally, beyond trust in different authorities, interpersonal trust may also be important. Thus, interpersonal trust may be a key predictor of the willingness to contribute to collective action during the COVID-19 pandemic.[18] Vaccinations is a form of collective action, where herd immunity is produced via the collective participation in vaccination programs,[19] and people may be more likely to participate if they trust others to do the same. To test these trust-related predictors of vaccination willingness, we therefore measure trust in the national health authorities, trust in scientists, trust in the government, and interpersonal trust in our surveys.

Turning to COVID-19 specific factors, we examine three factors: risk-perceptions, attitudes and compliance. Following a standard distinction within research on public attitudes,[20] we investigate the role of two categories of corona-related risk-perceptions: egotropic and sociotropic concern. While egotropic risk-perceptions relate to the consequences for the self or close and your family, sociotropic concern includes the consequences at the societal level, such as the country's economy and the capacity of the health care sector. Several studies have found that self-perceived risk of COVID-19 positively predicts acceptance of a potential COVID-19 vaccine.[10, 12, 21] Likewise, Wong et al. (2020) argued that perceived susceptibility to infection predicted the intention to take a future COVID-19 vaccine.[11] Thus, we expect that egotropic concern predict vaccination willingness. Furthermore, it is plausible that sociotropic concern predict vaccination willingness, since having a vaccine also can be seen as a form of other-directed behavior that protects individuals beyond the self. For example, empathy towards the vulnerable predicts vaccination willingness during the COVID-19 pandemic.[22] Accordingly, it is plausible that individuals who worry about the broader consequences of the coronavirus have higher vaccination willingness. Receiving the vaccine is a way to stop the transmission of COVID-19 and thereby reducing the cause of concern. On this basis, we include COVID-19-specific measures for both egotropic and a range of sociotropic concerns about the impact of the disease.

The next set of predictors we consider are attitudinal in nature. Prior literature on both vaccine hesitancy in general and in the context of the COVID-10 pandemic found that hesitancy is

integrated into a broader set of political attitudes and perceptions. Most prominently, people prone to conspiracy thinking are also more likely to be hesitant about vaccines.[23-24] This is also the case in the current context, where higher levels of coronavirus conspiracy thinking are associated with lower willingness to accept a future vaccine against COVID-19.[25, 21, although see 26]

The COVID-19 pandemic may spur anti-systemic sentiments on three different levels, reflecting the level of severity associated with it: (1) a general concern about the state's infringement on democratic rights, (2) support of public protests against the government's policies during the COVID-19 pandemic, and (3) belief in specific conspiracy theories related to COVID-19. We examine all these levels of anti-systemic sentiments and how they relate to vaccination willingness.

Furthermore, we examine the role of awareness of misinformation. From the literature we know that susceptibility to misinformation negatively affects people's willingness to accept a vaccine against COVID-19.[17] However, studies have also shown that pre-bunking can help cultivate "mental antibodies" against misinformation.[27-29] Thus, it is likely that awareness of misinformation is positively associated with vaccination willingness.

Next, we examine the feeling of "pandemic fatigue" as a potential correlate of vaccination willingness. The WHO has been warning about widespread fatigue among populations in the Fall of 2020.[30] It is plausible that people who feel fatigued are willing to do what it takes to end the pandemic including being vaccinated. However, perhaps paradoxically, fatigue could also generate an unwillingness to comply with further requirements from authorities including vaccinations. Thus, we include attitudes about concern for democratic rights, support for protests, conspiracy belief, awareness of misinformation, and fatigue in our model.

Finally, we examine the association between compliance during the COVID-19 pandemic and vaccine acceptance. The willingness to get vaccinated can be seen as yet another form of compliance with the health advice of authorities during the pandemic. Specifically, we investigate the potential correlates of behavior change, knowledge and support for restrictions. Individual-level behavior change to avoid the spread of infections and support for government restrictions are two direct measures of willingness to comply with other official initiatives during the pandemic. Accordingly, it is likely that larger behavior change and higher support is related to increased vaccination willingness. Finally, we include a psychological precursor to compliance. Knowledge about proper behavior was one of the best predictors of compliance

with physical distancing policies during the first wave of the pandemic.[31] Furthermore, perceived insufficient knowledge is significantly associated with general vaccine hesitancy.[14] Thus, it is plausible that knowledge about proper behavior during the pandemic is also associated with compliant behavior in the sense of taking a future COVID-19 vaccine. To sum up, we therefore examine behavior change, support for restrictions, and knowledge in our model.

Methods

Patient and public involvement. Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Data. We fielded quota-sampled surveys in eight countries from September 13 until November 7: Denmark, Sweden, the United Kingdom, the United States of America, Italy, France, Germany and Hungary (please see Table A1 in the appendix for an overview of the data collection). This period consists of four data rounds in Denmark, and three data rounds in the remaining countries with approximately 500 respondents per data round. In each of the eight countries in our sample, the survey company Epinion sampled adult respondents using online panels. Among the panelists invited to take our survey, the response rate (calculated as the fraction of complete responses over invited, eligible participants) across the countries in our sample was between 18 % (Hungary) and 64 % (the United States). The survey was conducted in line with the Danish ethical guidelines for conducting survey-based research involving human subjects. Survey respondents were quota sampled to match the population margins on age, gender, and geographic location for each of the eight countries in our study. We address imbalances by post-stratifying our sample data to match the demographic margins from the population. All statistical analyses presented in the manuscript employ these post-stratification weights.

Measures

All measures are self-reported from participant questionnaires. The key measures are vaccination willingness, trust in relevant authorities and groups, disease-specific risk-perceptions, disease-specific attitudes including conspiracy-related attitudes and propensities

to engage in other forms of disease-specific protective behavior. Table 1 provides an overview of question wordings and scales for these measures.

Table 1: Main measures in the study

	Questions	**Values**
Vaccination willingness	If the health authorities advise people like me to get an approved vaccine against the coronavirus, I will follow their advice.	1. Completely disagree 2. Somewhat disagree 3. Neither agree nor disagree 4. Somewhat agree 5. Completely agree
Trust	How much trust do you have in the following institutions regarding the coronavirus crisis? 1) The national health authorities 2) scientists	1. Not at all 2. To a lesser degree 3. To a certain degree 4. To a high degree
	Give your assessment on a scale from 0 to 10, where 0 indicates that you have no confidence in the government at all, and 10 indicates that you have full confidence in the government.	0. No confidence at al 1. 2. 3. 4. 5. 6. 7. 8. 9. 10. Full confidence
	Do you think that most people by and large are to be trusted, or that you cannot be too careful when it comes to other people?	0. You cannot be too careful 1. 2. 3. 4. 5. 6. 7. 8. 9. 10. Most people are to be trusted
Concern	To what degree are you concerned about the consequences of the corona-virus… (1) … for you and your family? (2) … for hospitals' ability to help the sick? (3) … for society's ability to help the disadvantaged? (4) … on social unrest and crime? (5) … on the country's economy?".	1. Not at all 2. To a lesser degree 3. To a certain degree 4. To a high degree
Attitudes	To what extent do you agree with the following statements?	1. Completely disagree 2. Somewhat disagree 3. Neither agree nor disagree

	(1) I'm concerned about my democratic rights in the current circumstances (2) I support the public protests against the government's policies during the COVID-19 pandemic (3) I believe the government is hiding important information from the public about the coronavirus and its cures (4) I have heard or read information about the coronavirus and its cures, which I believe was probably false (5) I do not think I can keep up with the restrictions against the coronavirus for much longer.	4. Somewhat agree 5. Completely agree
Compliance	To what degree do you feel that the current situation with the coronavirus has made you change your behavior to avoid spreading infection?	1. Not at all 2. To a lesser degree 3. To a certain degree 4. To a high degree
	To what degree do you feel that you know enough about what you as a citizen should do in relation to the coronavirus?	1. Not at all 2. To a lesser degree 3. To a certain degree 4. To a high degree
	As you may know, many countries have implemented various measures to stop the spread of the COVID-19 epidemic. We are interested in whether you support or oppose the following measures in your country: (1) Closing of schools and universities (2) Closing (or work from home) for all-but-essential workplaces (e.g. grocery shops, doctors) (3) Cancelling public events (4) Cancelling private gatherings with over 100 people (5) Closing public transportation (6) Ordering people to shelter-in-place (not leaving house with minimal exceptions) (7) Restricting internal movement between cities/regions (8) Ordering people to wear face masks in public places (9) Banning arrivals for foreign travelers from some regions.	1. Oppose 2. Support

Note: Mean and standard deviation of all measures is available in table A2.

Our outcome, vaccination willingness, is rescaled to range from 0-1, with higher values indicating higher levels of willingness to get a future COVID-19 vaccine. Furthermore, all measures of trust, concern and disease-specific attitudes are rescaled from 0-1, with higher values indicating higher levels of trust, concern and agreement with the disease-specific statements. For our compliance measures, we rescale behavior change and knowledge to range from 0-1, with higher values indicating higher levels of behavior change and knowledge. Furthermore, we create an index of support for restrictions by adding the nine measures of support for restrictions. The index is scaled to range from 0-1, with higher values indicating

higher levels of support for restrictions. "Do not know" answers are classified as missing and are not included in the analysis.

Finally, we include sex, age, education and political ideology as background variables. Sex is an indicator variable (0 for males; 1 for females). Age is a continuous variable asking respondents how old they are. Age is rescaled from 0-1, with 0 being the minimum age in the sample (18 years) and 1 being the maximum age (100 years). Education is an indicator variable based on the internationally comparable ISCED-scale (0 for non-tertiary education; 1 for tertiary education). Finally, political ideology is measured using the question: *"In political matters, people talk of 'the left' and 'the right'. How would you place your views on this scale, generally speaking?"*. Respondents answered on a scale from "1 – The left" to "11 – The right". This measure is rescaled to range from 0 to 1, with 0 indicating the ideological standpoint to the utmost left and 1 indicating the ideological standpoint to the utmost right.

Statistical analyses.

All predictors are scaled from 0-1 in the analysis below. Table A2 in the appendix reports the descriptive statistics for all the above correlates in our overall sample. Moreover, Figure A1 in the appendix shows an overview of all bivariate correlations.

In the analysis we present six models: (I) a model with all the bivariate correlations of vaccination willingness, (II) a trust model, (III) a concern model, (IV) an attitudes model, (V) a compliance model, and (VI) a full model that includes all predictors described above. Models II-VI include country dummies to control for country specific effects. Thus, our aim is to identify individual-level predictors of willingness to get a future COVID-19 vaccine. In the analysis, we use clustered robust standard errors at the country level. Furthermore, we present robustness tests in the Online Appendix where we replicate the analysis treating the 4-point scale measures of trust, concern, behavior change and knowledge as categorical variables instead of continuous (see Figure A2-A5). The results are essentially similar to those presented in the main text.

Results

First, we assess the overall distribution of vaccination willingness across the eight countries in our sample. Second, we present the results for the individual-level predictors of vaccination willingness.

Figure 1 shows the distribution of vaccination willingness, by country. The histograms display the country-specific distributions of vaccination willingness. The horizontal boxes show the 25th-75th percentile of the distributions. The white crosses and bars display mean and median values, respectively, while the whiskers show the minimum and maximum values.

[Figure 1 about here]

Across the eight countries, we observe large differences in the level of vaccination willingness. In Denmark and in the United Kingdom, the distribution is highly skewed towards willingness to get a future COVID-19 vaccine. Specifically, we observe the highest level of vaccination willingness in Denmark (79 %). Furthermore, we observe a high level of vaccination willingness in the United Kingdom (65 %). However, we observe only moderate levels of vaccination willingness in Italy (54 %), Germany (54 %), Sweden (50 %) and the United States (48 %). The lowest levels of vaccination willingness is observed in France (41 %) and Hungary (38 %). Furthermore, it is worth noticing that in six of the eight countries in our sample, more than 10 percent indicate complete disagreement with the idea to get the vaccine. In Hungary, one in three respondents chose this option.

Therefore, the results indicate that in most of the countries in our sample, vaccine skepticism is present and that a significant proportion of the population plans to refuse a future approved COVID-19 vaccine. These results underscore two important points: First, that vaccine skepticism is present in each of the countries in our sample demonstrates the importance of understanding the individual-level variation of vaccination willingness in order to understand the potential targets of health communication. Second, the large variation across countries emphasizes the need of a more thorough understanding of the importance of national context. We therefore also explore the macro-level correlations of vaccination willingness in the Discussion section.

On this basis, we turn towards understanding the individual-level predictors of willingness to get a future COVID-19 vaccine. Figure 2 and Table 2 present the results of the analysis. Specifically, Figure 2 reports the estimated correlations between vaccination willingness and individual-level predictors of vaccination willingness controlled for country dummies. The size of the estimated coefficients reported below reflects the difference in vaccination willingness when we compare individuals at the minimum and maximum values, respectively, for each of the correlates.

[Figure 2 about here]

Table 2: Individual-level predictors of vaccination willingness

	Model I Bivariate	Model II Trust	Model III Concern	Model IV Attitudes	Model V Compliance	Model VI Full model
Demographics						
Sex (female)	-0.058***	-0.053***	-0.062***	-0.052***	-0.070***	-0.059***
	(0.008)	(0.009)	(0.010)	(0.009)	(0.009)	(0.007)
Age	0.210***	0.162**	0.216**	0.139**	0.180**	0.145**
	(0.020)	(0.038)	(0.048)	(0.038)	(0.042)	(0.034)
Education (tertiary)	0.039***	0.027**	0.042**	0.026**	0.035**	0.021*
	(0.008)	(0.008)	(0.008)	(0.007)	(0.008)	(0.007)
Political ideology	-0.062***	-0.035	-0.039	-0.016	-0.022	-0.001
	(0.017)	(0.024)	(0.045)	(0.030)	(0.044)	(0.020)
Trust						
Health authorities	0.475***	0.221***				0.176***
	(0.013)	(0.020)				(0.013)
Scientists	0.464***	0.237***				0.165***
	(0.014)	(0.029)				(0.022)
The government	0.333***	0.120**				0.066**
	(0.014)	(0.032)				(0.017)
Interpersonal trust	0.191***	0.002				0.058*
	(0.016)	(0.020)				(0.017)
Concern						
You and your family	0.223***		0.252***			0.120***
	(0.015)		(0.037)			(0.022)
Hospitals	0.102***		0.063*			0.036*
	(0.015)		(0.024)			(0.015)
Society	0.078***		0.020			0.004
	(0.015)		(0.021)			(0.013)
Social unrest and crime	-0.034*		-0.100***			-0.044*
	(0.014)		(0.016)			(0.013)
The country's economy	0.043**		-0.008			0.017
	(0.016)		(0.038)			(0.024)
Attitudes						
Democratic rights	-0.244***			-0.092**		-0.035
	(0.013)			(0.022)		(0.021)
Conspiracy beliefs	-0.264***			-0.133***		-0.066**
	(0.012)			(0.023)		(0.017)
Support protests	-0.200***			-0.044		-0.012
	(0.012)			(0.029)		(0.021)
Misinformation	0.051***			0.100**		0.069**
	(0.015)			(0.019)		(0.015)
Fatigue	-0.202***			-0.073*		-0.035*
	(0.013)			(0.023)		(0.012)
Compliance						
Behavior change	0.273***				0.171***	0.087**
	(0.015)				(0.015)	(0.022)
Knowledge	0.167***				0.085*	-0.027
	(0.019)				(0.029)	(0.022)
Support for restrictions	0.299***				0.240***	0.105***
	(0.015)				(0.029)	(0.009)
Constant		0.102**	0.259***	0.532***	0.126**	0.017
		(0.020)	(0.046)	(0.034)	(0.029)	(0.033)
Observations	9,889	9,889	9,889	9,889	9,889	9,889
R^2	NA	0.246	0.157	0.168	0.178	0.246

Notes. Entries are unstandardized OLS regression coefficients from models with all variables standardized on a scale from 0-1. Clustered robust standard errors on country level in parentheses. Model 1 displays effects from bivariate models and, hence, a combined R^2 cannot be computed. Models II-VI include control for country dummies. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Examining the demographic predictors, we observe that being male, older, and having tertiary education is associated with higher vaccination willingness in case of an approved COVID-19 vaccine. Specifically, females are 5.9 percentage points less willing to receive a vaccine compared to males. Furthermore, age is a positive predictor of vaccination willingness. When we compare respondents at the minimum and maximum level of age in the sample, the difference is 14.5 percentage points. Finally, respondents with tertiary education are 2.1 percentage points more willing to receive an approved COVID-19 vaccine compared to respondents with non-tertiary education.

Focusing on trust, we observe that trust in the national health authorities is the strongest predictor of vaccination willingness. Specifically, the respondents who have the highest level of trust in the national health authorities are 17.6 percentage points more willing to receive an approved COVID-19 vaccine compared to those with the least trust in the national health authorities. The same pattern is observed for trust in scientists. Specifically, the respondents with the highest level of trust in scientists are 16.5 percentage points more willing to receive an approved COVID-19 vaccine compared to those with the lowest level of trust in scientists. Furthermore, trust in the government and interpersonal trust are also significant positive predictors of vaccination willingness. Respondents with the highest level of trust in the government are 6.6 percentage points more willing to receive an approved COVID-19 vaccine compared to those with the lowest level of trust in the government. Finally, respondents with the highest level of interpersonal trust are 5.8 percentage points more willing to receive an approved COVID-19 vaccine compared to respondents with the lowest level of interpersonal trust.

Looking into corona-specific concern, we find that egotropic concerns dominate sociotropic concerns in vaccination willingness. The respondents who are the most concerned about the consequences of the corona crisis for themselves and their families are 12 percentage points more willing to receive an approved COVID-19 vaccine compared to the least concerned respondents. For sociotropic concern, concern for the capacity of hospitals and concern for social unrest and crime are the only significant predictors. Specifically, the respondents who are the most concerned about the consequences of the corona crisis for the hospitals' ability to help the sick are 3.6 percentage points more willing to receive an approved COVID-19 vaccine compared to the least concerned respondents. Furthermore, the respondents who are the most concerned about the consequences of the corona crisis for social unrest and crime are 4.4

percentage points less willing to receive an approved COVID-19 vaccine compared to the least concerned respondents.

Focusing on corona-specific attitudes, we observe that awareness of misinformation is positively associated with vaccination willingness, while conspiracy belief and fatigue are negatively associated with vaccination willingness. Specifically, respondents who think that they have been exposed to misinformation are 6.9 percentage points more willing to receive an approved COVID-19 vaccine. Furthermore, respondents who have the highest level of conspiracy belief, and thus thinking that the government is hiding important information about the coronavirus and its cures, are 6.6 percentage points less willing to receive an approved COVID-19 vaccine. Finally, respondents with the highest level of fatigue are 3.5 percentage points less willing to receive an approved vaccine.

Finally, looking at compliance, we see that both behavior change and support for restrictions positively predicts vaccination willingness. Specifically, respondents who have changed their behavior the most to avoid spreading infection are 8.7 percentage points more willing to receive an approved COVID-19 vaccine compared to respondents who have changed their behavior the least. Finally, respondents who are most supportive of restrictions are 10.5 percentage points more willing to receive a vaccine compared to respondents who are the least supportive of restrictions.

While the overall patterns are relatively uniform across countries, we observe some notable differences (see Figure A6 in the Online Appendix). In the United Kingdom, trust in the national health authorities is not a significant predictor of vaccination willingness. Furthermore, egotropic concern is not a significant predictor of vaccination willingness in Denmark and Italy. Moreover, there is no uniform patterns in the relationship between political ideology and vaccination willingness across countries. Finally, subgroup analyses assessing potential heterogeneity across demographic groups show that the results are essentially homogenous across sex, age and educational level (see Figures A8-A10 in the Online Appendix).

Discussion

In this paper, we have investigated (1) the level of willingness to receive an approved COVID-19 vaccine, and (2) the individual-level predictors of vaccination willingness. The data show large variation in vaccination willingness both across countries and within many of the countries in our sample, with a significant proportion saying that they would refuse a future approved COVID-19 vaccine. This highlights the need for understanding the individual-level variation underlying vaccine skepticism and identifying potential targets for health communication to increase willingness.

When each predictive factor is assessed individually, these present results demonstrate that the key individual drivers of willingness to receive an approved COVID-19 vaccine are (1) trust in the national health authorities, and (2) personal health concerns. First, we found that respondents who trust the national health authorities were most willing to receive a COVID-19 vaccine compared to respondents who lack trust in the national health authorities. Second, we found that the people who are the most concerned for the consequences of the corona crisis for themselves and their families had high vaccination willingness. While these factors are the most prominent when everything is assessed individually, the present data also shows that vaccine skepticism is interwoven into a larger web of attitudes and behaviors related to anti-systemic sentiments. Hence, in addition to trust in health authorities, a lack of willingness was also related to concerns about democratic rights, endorsement of conspiracy beliefs and a lack of compliance with advice about changing behavior to avoid spreading infections.

As a final explorative analysis, we assess whether these factors also help explain the cross-national variation in vaccination willingness. To this end, we examine the correlations between vaccination willingness at the national level and each of the different independent measures aggregated for each country. All of these correlations are available in Figure A11 in the Online Appendix. In Figure 3, we present the correlations for key variables highlighted above: Trust in health authorities, egotropic concern, conspiracy beliefs and behavior change. While the analysis is highly limited by the fact that it only includes eight national cases, it is nonetheless strikingly informative. While differences in egotropic concern are not strongly related to cross-national differences, country averages in the anti-systemic measures, especially (lack of) trust in health authorities, are exceptionally closely related to country averages in vaccination willingness. Trust in health authorities does not just explain differences in vaccination willingness between individuals but also between countries.

[Figure 3 about here]

In sum, these analyses point to the significant challenges involved in convincing vaccine skeptics. The web of anti-systemic attitudes and distrust that vaccine skepticism is interwoven in makes it difficult to craft efficient health communication, as the effectiveness of communication is fundamentally contingent on the preceding existence of trust in its source. This challenge might be further deepened during the COVID-19 pandemic as research suggests that the stress of the pandemic and the restrictions itself fuels anti-systemic beliefs.[9] In this regard, it is also notable that feelings of "pandemic fatigue", which according to the WHO is on the rise,[30] is *negatively* related to vaccination willingness, suggesting paradoxically that vaccination willingness may in fact become less pronounced as the pandemic continues. It is important to note that these results are observational rather than causal in nature. Nonetheless, they suggest that the best communication target is the consequences of infections for the self and close others. In addition, these results underscore the key importance of health and political authorities to strive to uphold trust to the maximum extent during the pandemic. This is not just crucial for managing the pandemic until a vaccine arrives but also for ending the pandemic when the vaccine arrives.

Figure captions and legends

Figure 1: Vaccination willingness for an approved COVID-19 vaccine

Note: Histograms: display the distributions of vaccination willingness, by country. Boxplots: boxes hold the 25th-75th percentile, white bars are median values, white crosses are mean values, while whiskers are minimum and maximum values.

Figure 2: Individual-level correlations of vaccination willingness

Note: N = 9,889. Black circles are the estimated correlations based on model I-VI in Table 1. Models II-VI include control for country dummies. Horizontal bars are the associated 95 % confidence interval.

Figure 3: Macro-level correlations of vaccination willingness

Note: The figure plots country averages for vaccination willingness and country averages for four measures: Trust in health authorities, egotropic concern related to COVID-19, endorsement of COVID-19 conspiracy beliefs and the degree of changed behavior to avoid spreading infections during the COVID-19 pandemic. Reported correlations are pearson's r.

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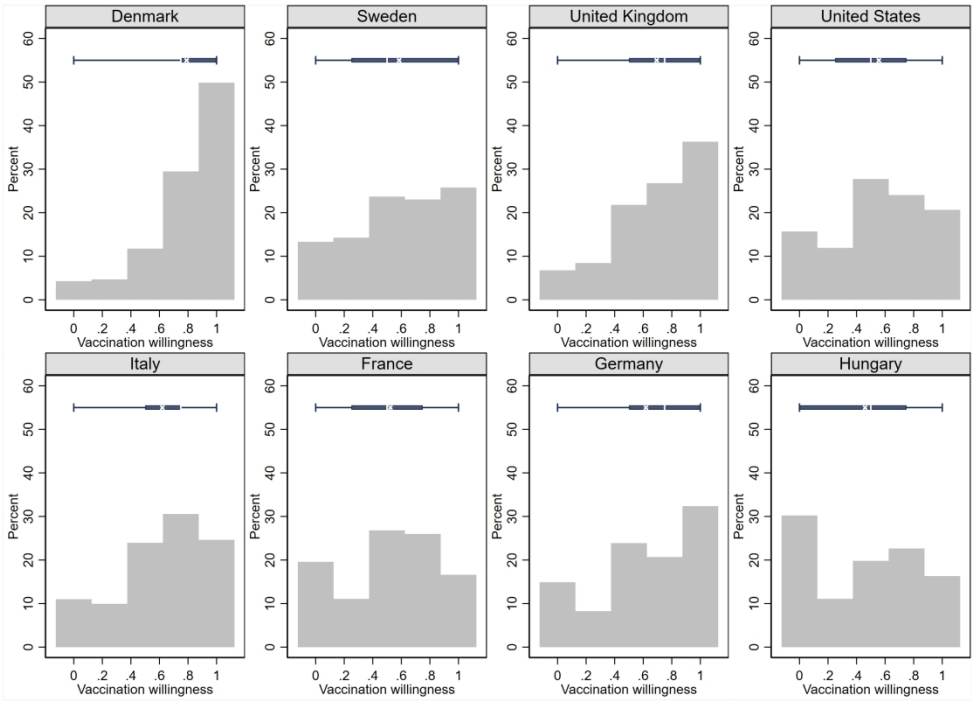

Figure 1: Vaccination willingness for an approved COVID-19 vaccine

Note: Histograms: display the distributions of vaccination willingness, by country. Boxplots: boxes hold the 25th-75th percentile, white bars are median values, white crosses are mean values, while whiskers are minimum and maximum values.

846x615mm (72 x 72 DPI)

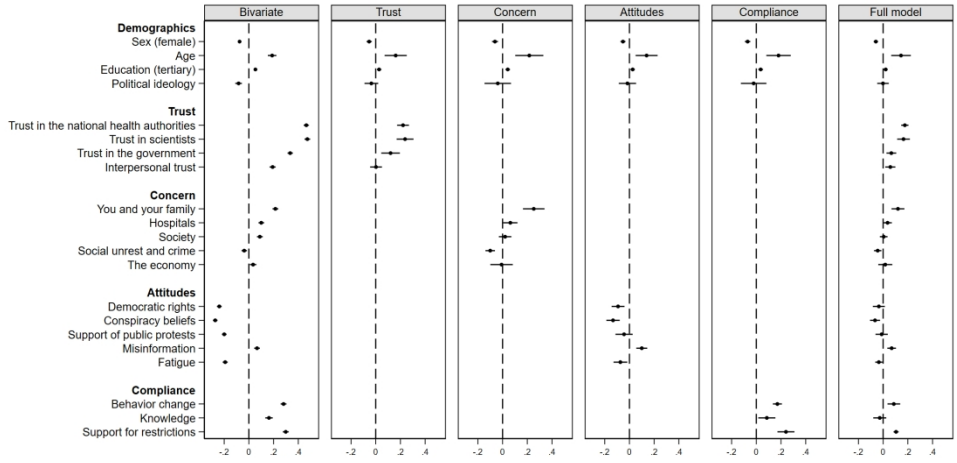

Figure 2: Individual-level correlations of vaccination willingness

Note: N = 9,889. Black circles are the estimated correlations based on model I-VI in Table 1. Models II-VI include control for country dummies. Horizontal bars are the associated 95 % confidence interval.

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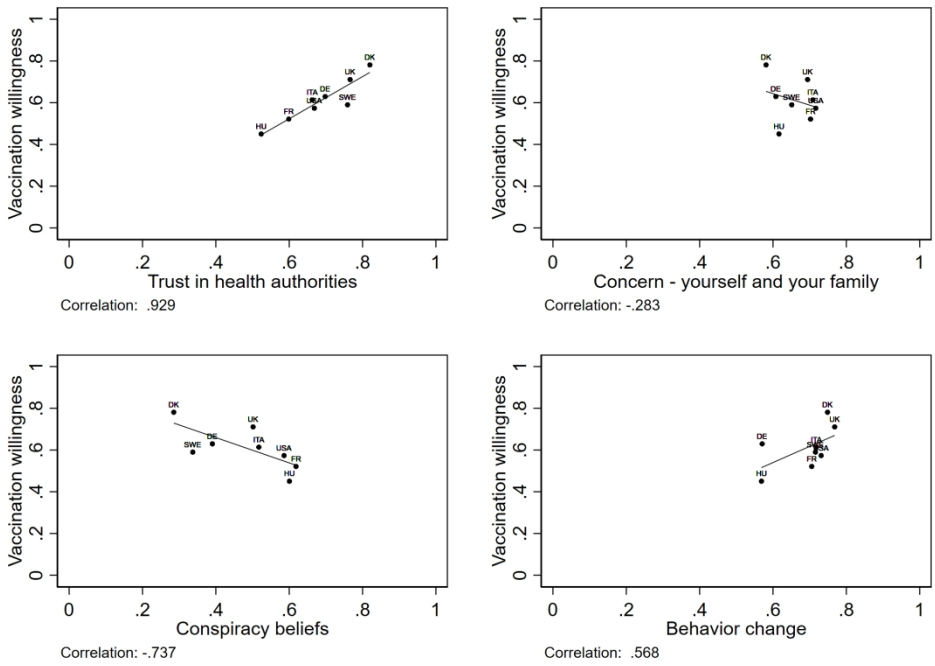

Figure 3: Macro-level correlations of vaccination willingness

Note: The figure plots country averages for vaccination willingness and country averages for four measures: Trust in health authorities, egotropic concern related to COVID-19, endorsement of COVID-19 conspiracy beliefs and the degree of changed behavior to avoid spreading infections during the COVID-19 pandemic. Reported correlations are pearson's r.

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Online appendix

Table A1: Overview of data collection

Country	Dates	Obs.
Denmark	September 13 – November 7	1,364
Sweden	September 13 – November 7	1,052
United Kingdom	September 13 – November 7	1,185
United States	September 13 – November 7	1,269
Italy	September 13 – November 7	1,329
France	September 13 – November 7	1,247
Germany	September 13 – November 7	1,215
Hungary	September 13 – November 7	1,228

Table A2: Descriptive statistics

	Mean	SD	Min	Max	N
Vaccination willingness	0.61	0.34	0	1	9,889
Demographics					
Sex (female)	0.48	0.50	0	1	9,889
Age	0.35	0.19	0	1	9,889
Education (tertiary)	0.48	0.50	0	1	9,889
Political ideology	0.50	0.25	0	1	9,889
Trust					
Trust in national health authorities	0.68	0.29	0	1	9,889
Trust in scientists	0.74	0.27	0	1	9,889
Trust in the government	0.52	0.30	0	1	9,889
Interpersonal trust	0.48	0.27	0	1	9,889
Concern					
You and your family	0.66	0.28	0	1	9,889
Hospitals	0.68	0.29	0	1	9,889
Society	0.68	0.29	0	1	9,889
Social unrest and crime	0.63	0.31	0	1	9,889
The country's economy	0.78	0.26	0	1	9,889
Attitudes					
Democratic rights	0.48	0.34	0	1	9,889
Conspiracy beliefs	0.48	0.35	0	1	9,889
Support protests	0.38	0.35	0	1	9,889
Misinformation	0.62	0.29	0	1	9,889
Fatigue	0.37	0.33	0	1	9,889
Compliance					
Behavior change	0.70	0.28	0	1	9,889
Knowledge	0.78	0.22	0	1	9,889
Support for restrictions	0.65	0.27	0	1	9,889

Figure A1: Bivariate correlations

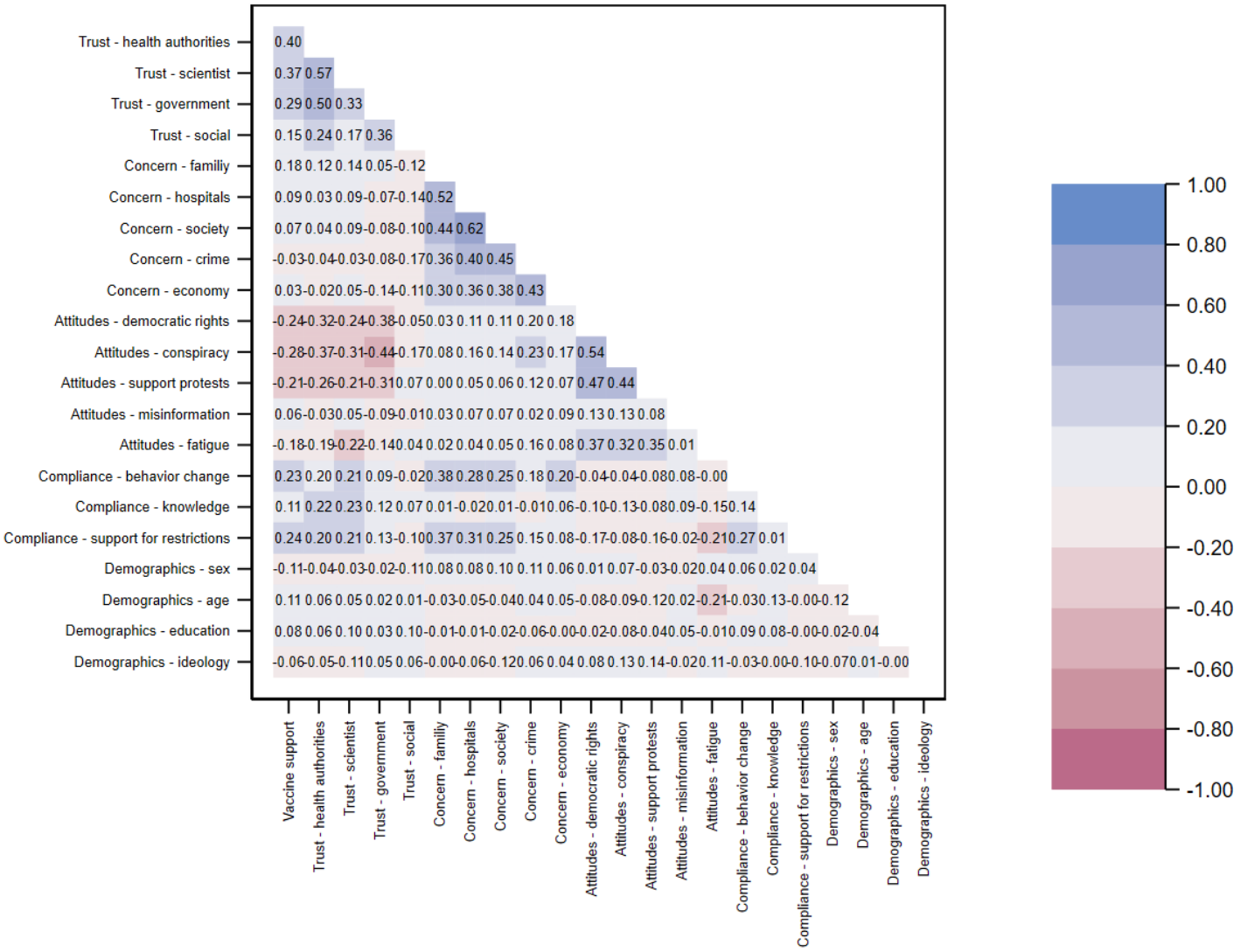
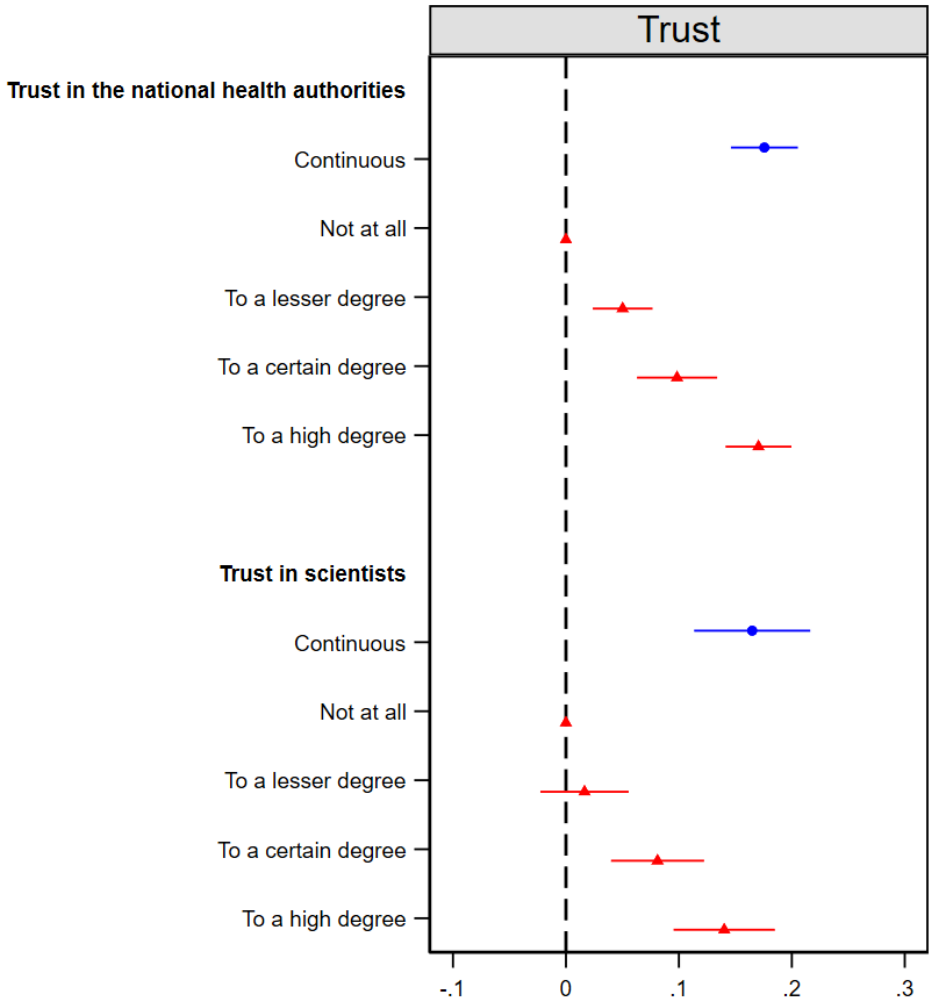
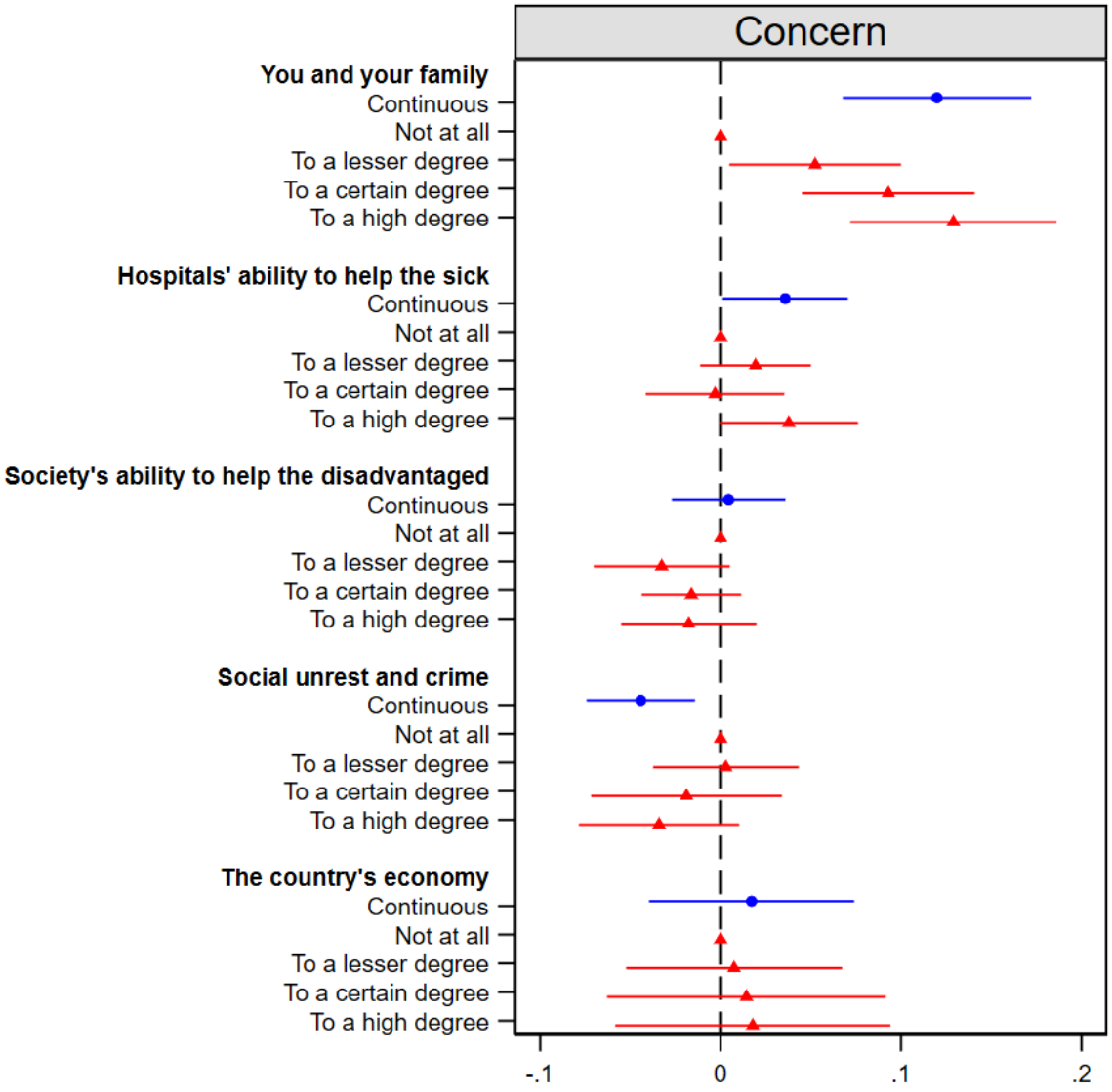


Figure A2: Replicating the analysis with categorical trust variables



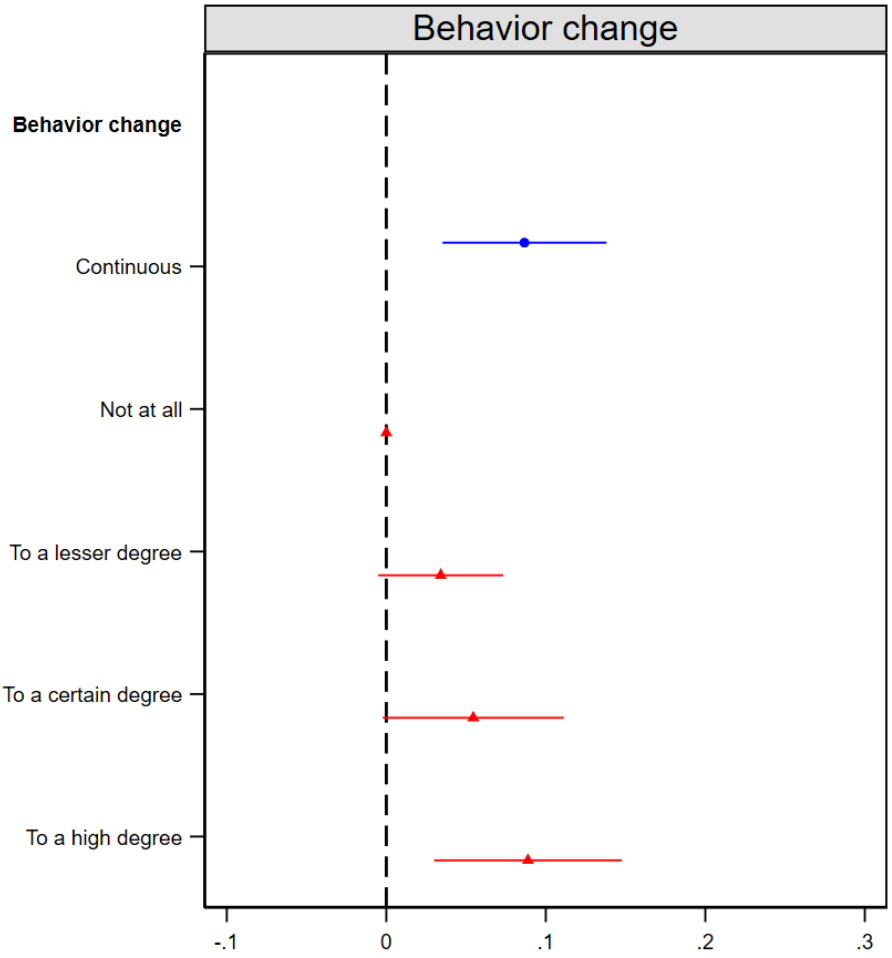
Note: N = 9,889. Blue circles are the estimated correlations based on model VI in Table 1 (continuous trust variables). Red triangles are the estimated correlations based on the same model, using categorical trust variables instead. Both models include control for country dummies. Horizontal bars are the associated 95 % confidence intervals.

Figure A3: Replicating the analysis with categorical concern variables



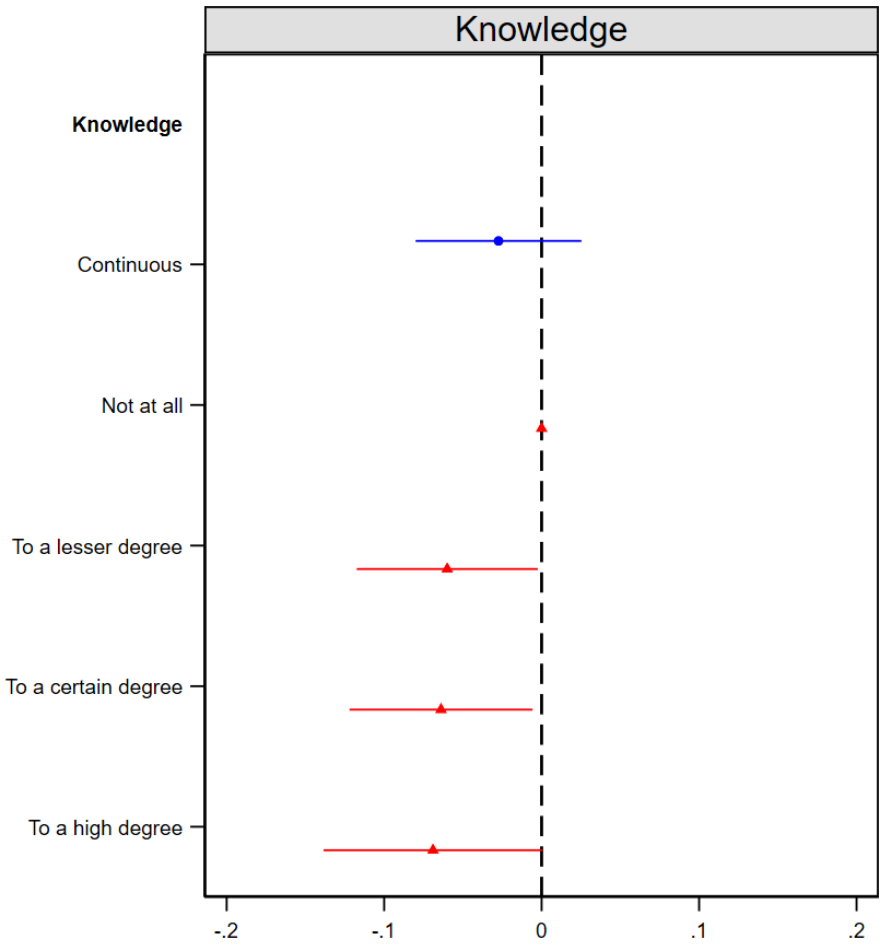
Note: N = 9,889. Blue circles are the estimated correlations based on model VI in Table 1 (continuous concern variables). Red triangles are the estimated correlations based on the same model, using categorical concern variables instead. Both models include control for country dummies. Horizontal bars are the associated 95 % confidence intervals.

Figure A4: Replicating the analysis with a categorical behavior change variable



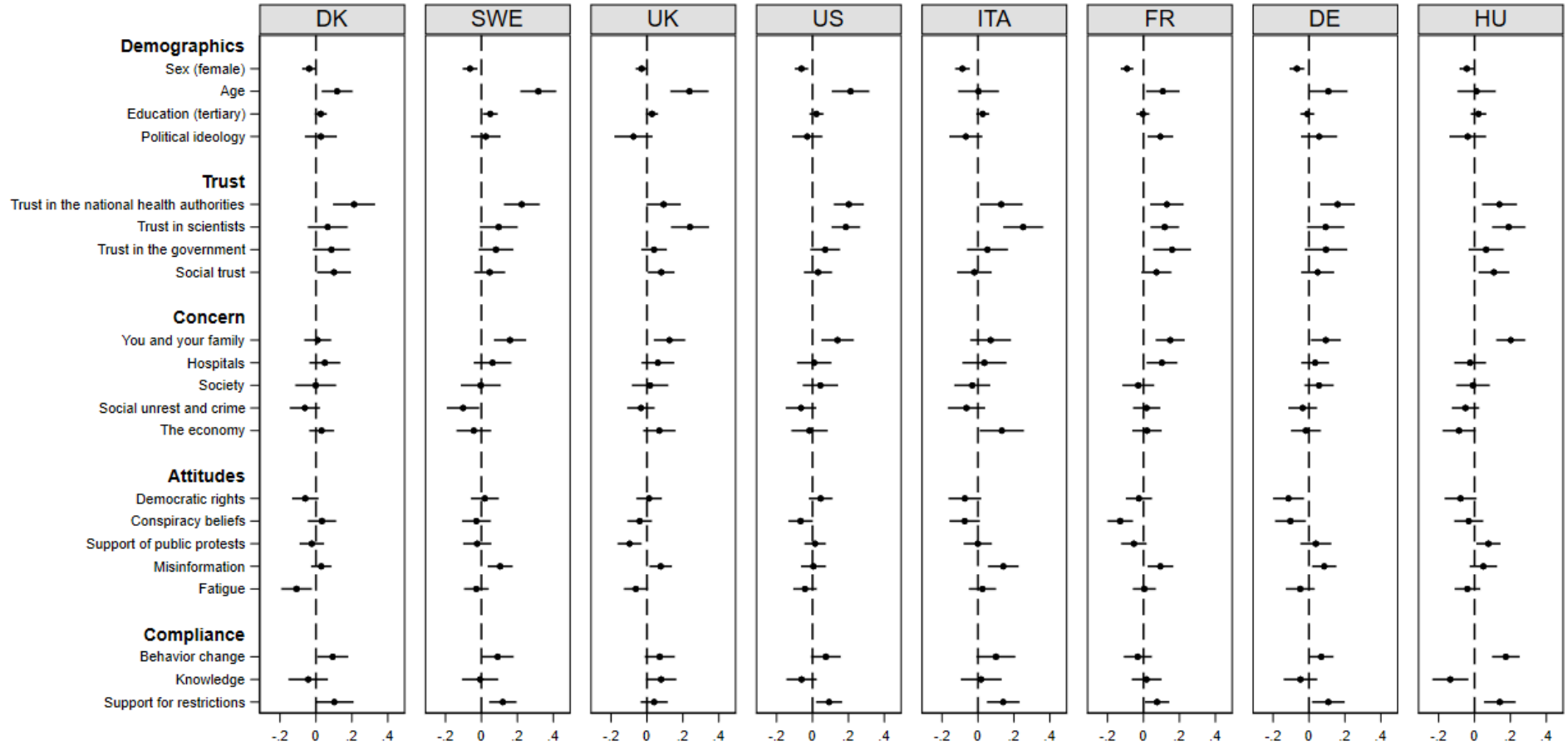
Note: N = 9,889. Blue circles are the estimated correlations based on model VI in Table 1 (continuous behavior change variable). Red triangles are the estimated correlations based on the same model, using a categorical behavior change variable instead. Both models include control for country dummies. Horizontal bars are the associated 95 % confidence intervals.

Figure A5: Replicating the analysis with a categorical knowledge variable



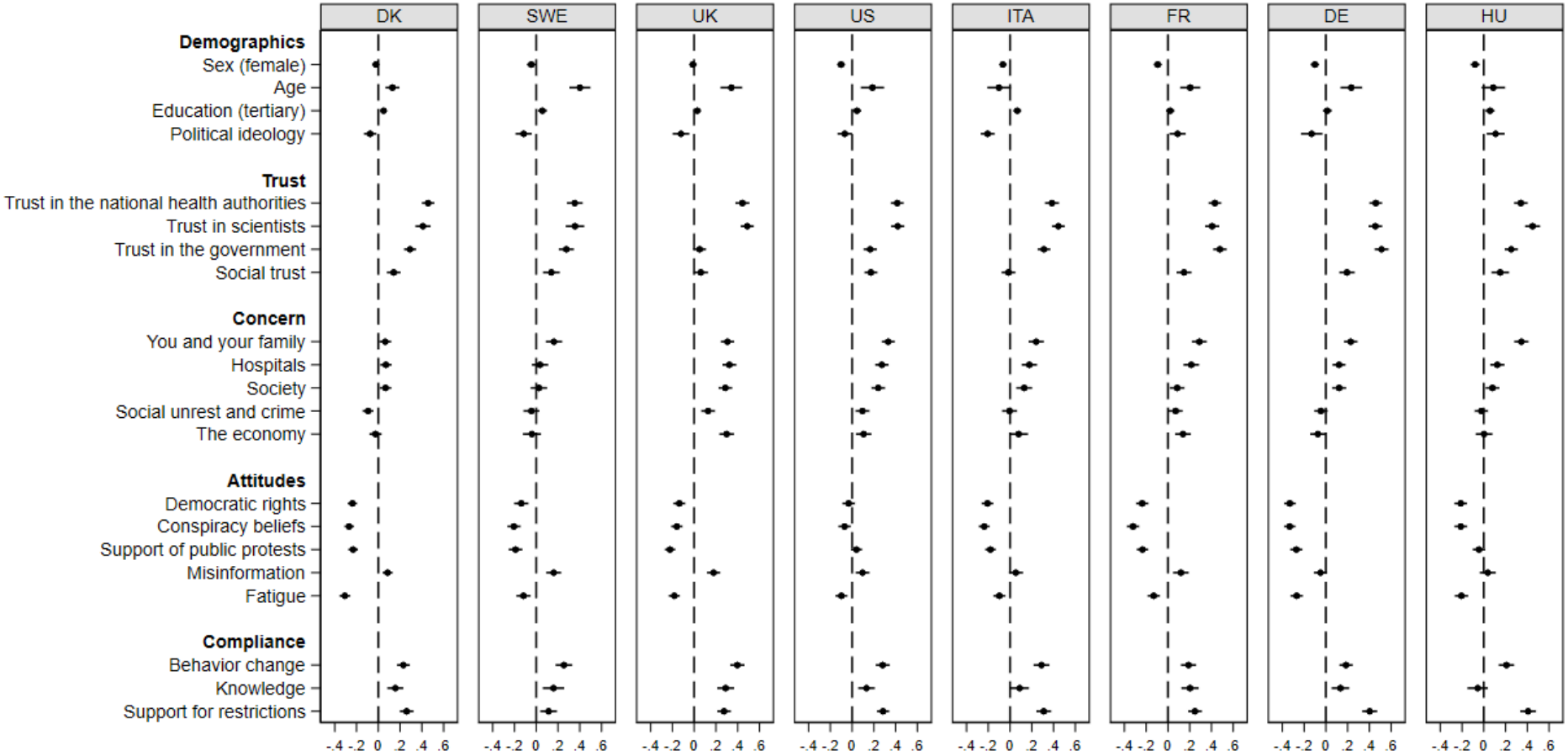
Note: N = 9,889. Blue circles are the estimated correlations based on model VI in Table 1 (continuous knowledge variable). Red triangles are the estimated correlations based on the same model, using a categorical knowledge variable instead. Both models include control for country dummies. Horizontal bars are the associated 95 % confidence intervals.

Figure A6: Individual-level correlations of vaccination willingness by country



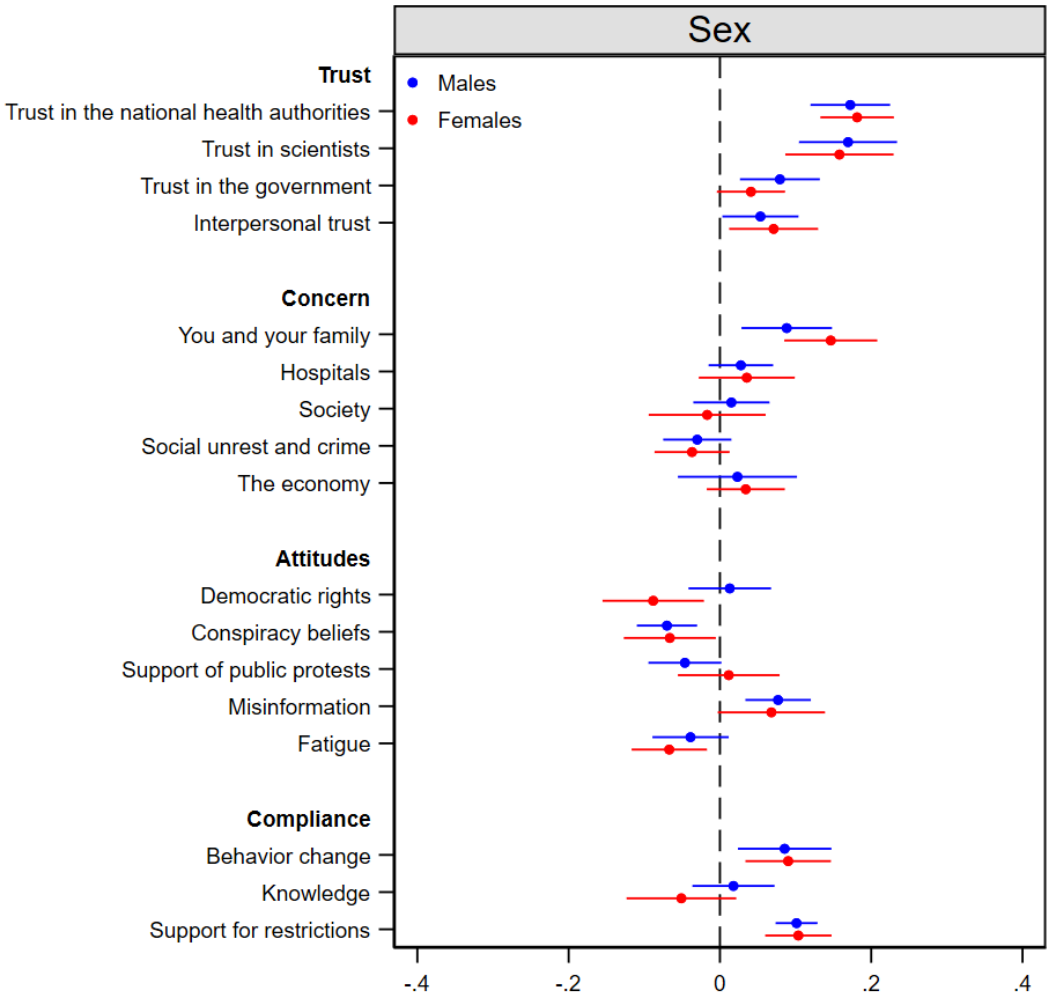
Note: N = 9,889. Black circles are the estimated correlations. Horizontal bars are the associated 95 % confidence intervals.

Figure A7: Bivariate correlations by country



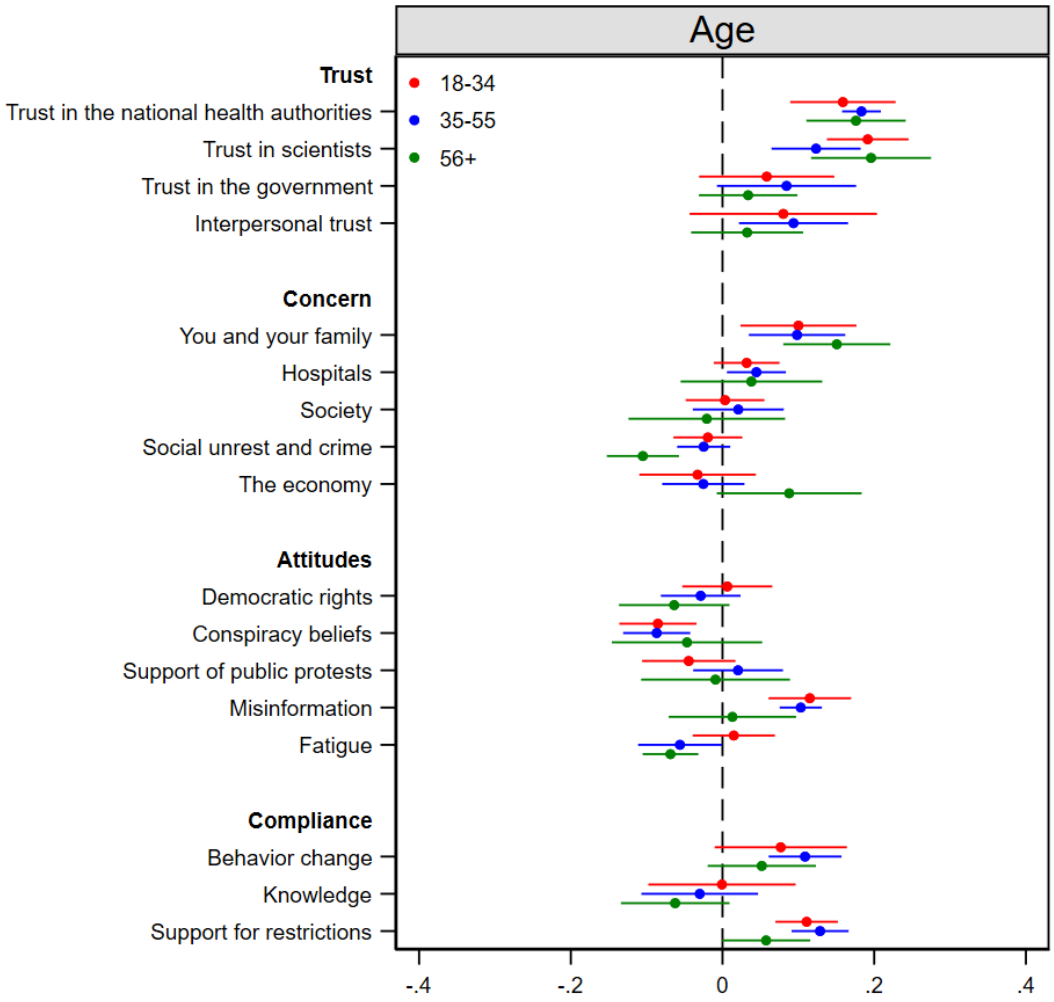
Note: N = 9,889. Black circles are the estimated bivariate correlations. Horizontal bars are the associated 95 % confidence intervals.

Figure A8: Subgroup analysis - sex



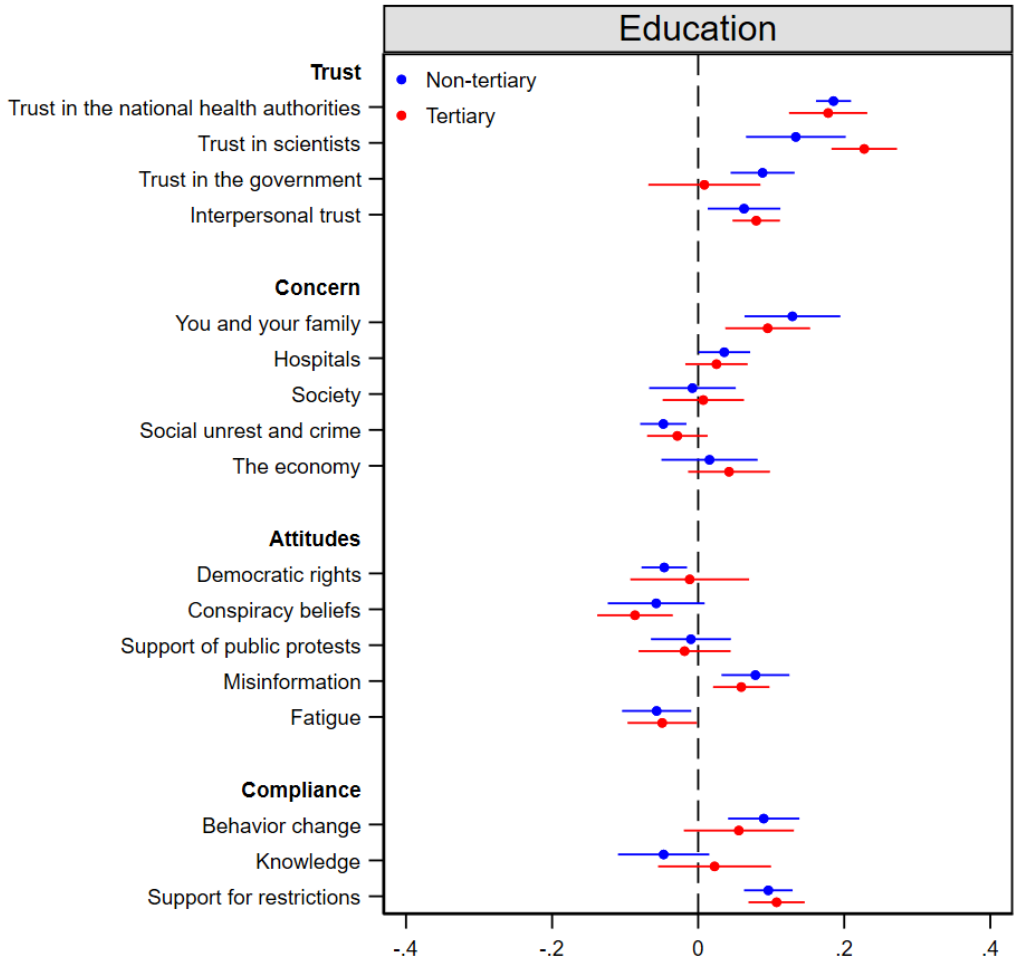
Note: N = 9,889. Circles are the estimated correlations. Horizontal bars are the associated 95 % confidence intervals.

Figure A9: Subgroup analysis - age



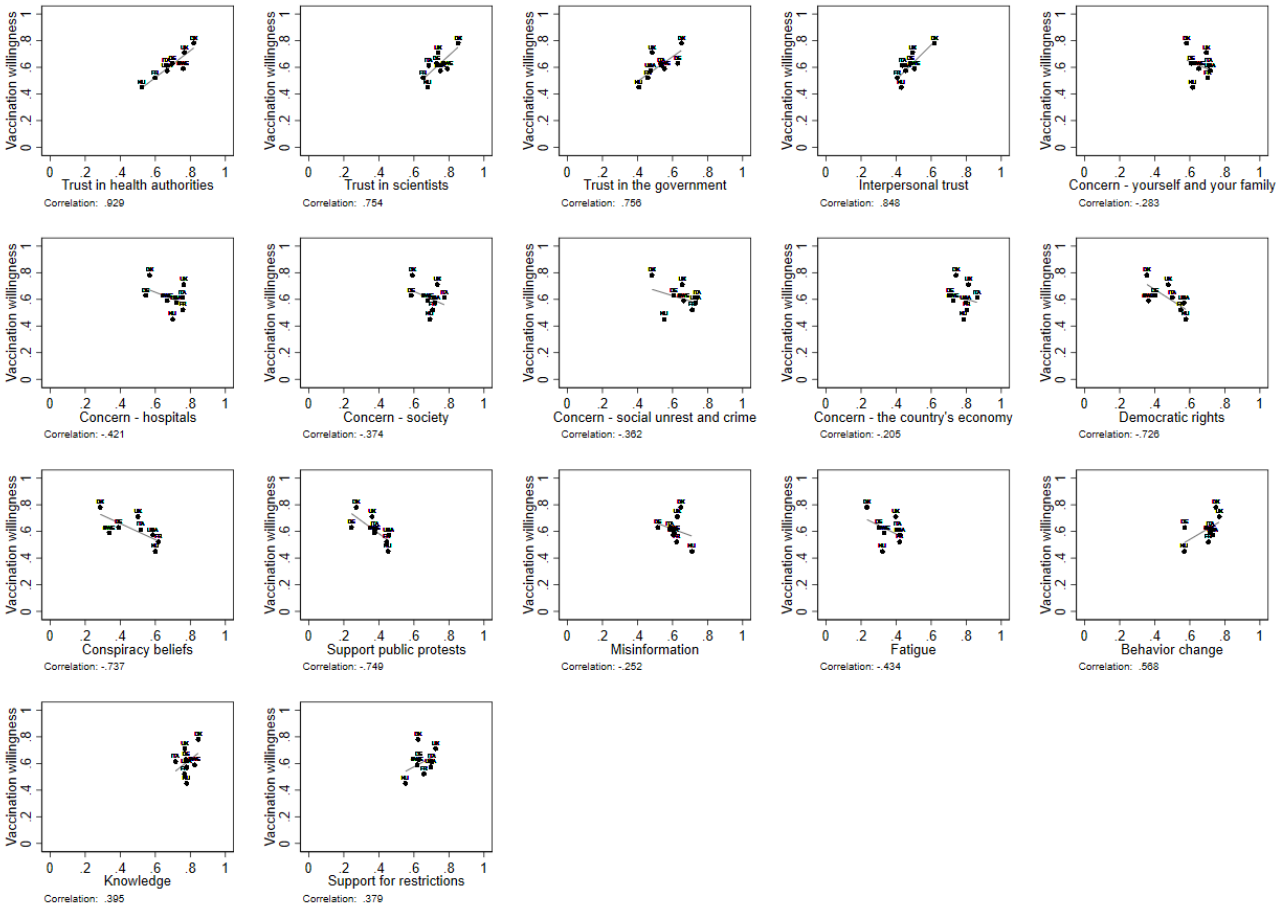
Note: N = 9,889. Circles, triangles and squares are the estimated correlations. Horizontal bars are the associated 95 % confidence intervals.

Figure A10: Subgroup analysis - education



Note: N = 9,889. Circles and triangles are the estimated correlations. Horizontal bars are the associated 95 % confidence intervals.

Figure A11: Macro-level correlations of vaccination willingness



Note: The figure plots country averages for vaccination willingness and country averages for the range of non-background measures. Reported correlations are pearson's r.

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4-5
Methods			
Study design	4	Present key elements of study design early in the paper	8
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	8
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	8
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	9 (+ table 1)
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	9 (+ table 1)
Bias	9	Describe any efforts to address potential sources of bias	
Study size	10	Explain how the study size was arrived at	8
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	10
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	10
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	9
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	10
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	2 (table A1)
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Table A2
		(b) Indicate number of participants with missing data for each variable of interest	
Outcome data	15*	Report numbers of outcome events or summary measures	10-11 (+ figure 1)
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	12-13 (figure 2, table 2)
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	10 + 13 (Online appendix)
Discussion			
Key results	18	Summarise key results with reference to study objectives	14
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	14-15
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	15
Generalisability	21	Discuss the generalisability (external validity) of the study results	14
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	3

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Public Acceptance of COVID-19 Vaccines: Cross-National Evidence on Levels and Individual-Level Predictors Using Observational Data

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Complete List of Authors:	Lindholt, Marie Fly; Aarhus Universitet, Political Science Jørgensen, Frederik; Aarhus University, Department of Political Science Bor, Alexander; Aarhus University, Department of Political Science Petersen, Michael; Aarhus University, Department of Political Science
Primary Subject Heading:	Public health
Secondary Subject Heading:	Epidemiology
Keywords:	COVID-19, PUBLIC HEALTH, EPIDEMIOLOGY

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March 8, 2021

Public Acceptance of COVID-19 Vaccines: Cross-National Evidence on Levels and Individual-Level Predictors Using Observational Data

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Abstract

Objectives

The management of the COVID-19 pandemic hinges on the approval of safe and effective vaccines but, equally importantly, on high vaccine acceptance among people. To facilitate vaccination acceptance via effective health communication, it is key to understand levels of vaccine skepticism and the demographic, psychological and political predictors. To this end, we examine the levels and predictors of acceptance of an approved COVID-19 vaccine.

Design, setting and participants

We examine the levels and predictors of acceptance of an approved COVID-19 vaccine in large online surveys from eight Western democracies that differ in terms of the severity of the pandemic and their response: Denmark, France, Germany, Hungary, Sweden, Italy, United Kingdom, and United States (total N = 18,231). Survey respondents were quota sampled to match the population margins on age, gender, and geographic location for each country. The study was conducted from September 2020 to February 2021, allowing us to assess changes in acceptance and predictors as COVID-19 vaccine programs were rolled out.

Outcome measure

The outcome of the study is acceptance of a COVID-19 vaccine approved and recommended by health authorities.

Results

The data reveal large variations in vaccine acceptance that ranges from 82 % in Denmark to 52 % in Hungary. Lack of vaccine acceptance is associated with lack of trust in authorities and scientists, conspiratorial thinking, and a lack of concern about COVID-19.

Conclusion

Most national levels of vaccine acceptance fall below estimates of the required threshold for herd immunity. The results emphasize the long-term importance of building trust in preparations for health emergencies such as the current pandemic. For health communication, the results emphasize the importance of focusing on personal consequences of infections and debunking of myths to guide communication strategies.

Article Summary

Strengths and limitations of this study

- Large samples that are reflective of the populations of eight different countries, allowing us to examine the generalizability of findings and the factors underlying cross-national differences.
- A broad-based assessment of potential correlates of vaccine acceptance, including both demographics, political, and COVID-specific factors.
- Analyses that includes observations both pre- and post-approval of COVID-19 vaccines.
- Observational data which limits causal traction.
- Self-reported vaccine acceptance can be subject to social desirability bias, and does not necessarily translate into actual vaccination rates.

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Ethical statement: The study complies with Aarhus University's Code of Conduct as well as the Committee Act of the Danish National Committee of Health Research Ethics, which states that "Surveys using questionnaires and interviews that do not involve human biological material (section 14(2) of the Committee Act)" are exempted from approval (https://en.nvk.dk/how-to-notify/what-to-notify)

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Background

A vaccine against COVID-19 is a "vital tool" in the management of the current pandemic.[1] Accordingly, extraordinary resources have been invested into vaccine development with unprecedented speed. Yet, even as approved vaccines become available, societies across the world still face another challenge: Vaccine skepticism.

As of late 2020, researchers estimated that up to 82 percent of a country's population may need to be vaccinated in order to reach herd immunity against SARS-CoV-2,[2-3] and the emergence of new virus variants implies that individuals may need to get vaccinated repeatedly. However, general vaccine hesitancy has been on the rise in recent years in many countries.[4-5] This has been the case for many non-COVID-19 vaccine programs, and is likely to pose a challenge for COVID-19 vaccines.[6-7] Consistent with this, initial cross-national survey evidence suggests that substantially fewer people worldwide are willing to get vaccinated than would be necessary; and that some countries – e.g. Russia, Poland and France – face strikingly high levels of skepticism.[8] Thus, a key challenge for pandemic management is for health authorities across the world to encourage people to accept approved COVID-19 vaccines through careful approval procedures and effective health communication. This latter challenge emphasizes the importance of understanding why people are hesitant about taking vaccines. Such knowledge is crucial for guiding communication in a way that increase vaccine acceptance and for understanding how to prepare for future health emergencies.

In this manuscript, we *first* present descriptive analyses of the acceptance of a COVID-19 vaccine approved and recommended by health authorities across eight Western democracies. *Second*, we investigate individual-level predictors of vaccine acceptance. The study was conducted from the fall of 2020 to the winter of 2021. This data collection thus allows us to track levels and predictors of vaccine acceptance as vaccines were approved using large-scale cross-national surveys including a broad set of potential predictors, including political predictors, which are less-often explored in traditional health research. Given the scale and broad impact of a pandemic crisis, however, such broader predictors may be particularly relevant to explore.

Potential predictors: Who are expected to accept a COVID-19 vaccine?

To organize our expectations about the individual-level predictors of vaccine acceptance during the COVID-19 pandemic, we draw on one of the most comprehensive frameworks for understanding the antecedents of vaccine acceptance; the 5C model from Betsch et al. (2018).[9] According to the 5C model, five psychological antecedents drive vaccine acceptance: *confidence, constraints, complacency, calculation and collective responsibility*. While we consider multiple predictors that are often not considered within this model, we strengthen the model's coverage by theorizing the link between the components of the model and the novel predictors that may be important for vaccine acceptance during the COVID-19 pandemic.

Confidence is defined as trust in (i) the effectiveness and safety of vaccines, (ii) the system that delivers them, and (iii) the motivation of policy-makers who decide on the need of vaccines.[9-10] Here, we consider two categories of predictors that reflect the underlying dimensions of confidence. First, we broadly tap into the second dimension of the definition by focusing on trust in a range of actors. Second, we investigate a range of disease-specific attitudes that broadly reflect the third dimension of the definition.

Empirically, trust is a crucial predictor of vaccine acceptance. Guay et al. (2019), for example, found that distrust in public health authorities is associated with general vaccine hesitancy.[11] Similarly, people who trust official authorities, were more likely to accept the HPV vaccine.[12] Initial work on COVID-19 vaccines also demonstrates that those who have higher trust in scientists are more willing to get vaccinated.[13]

Furthermore, the literature on vaccine hesitancy has found that hesitancy is integrated into a broader set of political attitudes and perceptions. Political ideology has been found to be related to vaccine hesitancy as conservative individuals are less likely to trust authorities.[14] Furthermore, it is a standard finding in political science that individuals are less likely to accept decisions from other political parties than they one they identify with or vote for.[15] Thus, it is plausible that people who have voted for the government party/candidate are more likely to accept a vaccine, since the vaccine program is a part of the governments' response to the pandemic. In addition to these standard political attitudes, more extreme attitudes may also influence confidence in vaccines. Most prominently, people prone to conspiracy thinking are more likely to be hesitant about vaccines.[16-17] In the current context, higher levels of

coronavirus conspiracy thinking have also been found to be associated with lower acceptance of future vaccines against COVID-19.[18, 19, although see 20] Consequently, it can be expected that the COVID-19 pandemic may elicit anti-systemic sentiments. We examine three levels of anti-systemic sentiments and how they relate to vaccine acceptance, including (1) concern for democratic rights, (2) support of public protests against government policies, and (3) beliefs in specific conspiracy theories related to COVID-19. Finally, we also examine the role of awareness of misinformation. From the literature, we know that susceptibility to misinformation negatively affects people's acceptance of a vaccine against COVID-19.[21] However, studies have also shown that pre-bunking can help cultivate "mental antibodies" against misinformation.[22-23] Thus, it is likely that awareness of misinformation is positively associated with vaccine acceptance.

Constraints refer to the structural and psychological barriers, impeding the implementation of vaccination intentions into behavior.[9] We consider the feeling of "pandemic fatigue" as such a barrier and thus a potential correlate of vaccine acceptance. While the WHO has been warning about fatigue among populations in the fall of 2020,[24-25] it is plausible that people who feel fatigued are willing to do what it takes to end the pandemic including being vaccinated. However, perhaps paradoxically, fatigue could also generate an unwillingness or incapability to comply with further requirements including vaccinations. Furthermore, we include the sense of having sufficient knowledge about behavioral recommendations as another psychological barrier. A sense of self-efficacy about proper behavior was one of the best predictors of compliance with physical distancing policies during the first wave of the pandemic.[26] Furthermore, perceived insufficient knowledge is significantly associated with general vaccine hesitancy.[11] Finally, we assess remaining psychological constraints by assessing to what extent people report being able to change their behavior in accordance with the recommendations from the health authorities during the pandemic. This general measure of behavior change should serve as a proxy for the range of constraints that may serve as a barrier for action over and beyond the directly assessed factors.

Complacency "exists where perceived risks of vaccine-preventable diseases are low and vaccination is not deemed a necessary preventive action".[9-10] Here we consider two types of predictors, including demographic factors and corona-specific risk-perceptions.

First, a set of demographic predictors are expected to be associated with complacency. Thus, prior studies have found that males are more likely than females to accept a potential COVID-

19 vaccine [27-29], potentially due to sex-based differences in COVID-19 mortality.[27] Likewise older people are expected to be more willing to take a vaccination due to higher risks of severe infections. This is supported by Lazarus et al. (2020)[8] and Hacquin et al. (2020)[29], while neither Dror et al. (2020)[27] nor Wong et al. (2020)[28] found any age differences in vaccine acceptance. As a final demographic variable, we also consider education, even though this variable may influence vaccine acceptance through other dimensions than complacency (e.g., confidence). The findings of prior studies on vaccine hesitancy are mixed with regards to education, indicating that that the association between education and vaccine hesitancy is context specific.[30] To illustrate, whereas Guay et al. (2019) find that lower education is associated with general vaccine hesitancy in Canada,[11] Wagner et al. (2019) find that educational level is *not* associated with general vaccine hesitancy across five low-middle and middle-income countries.[30] Similarly, Bertoncello et al. (2020) find that while low parent education is significantly associated with general vaccine hesitancy, it is *not* associated with hesitancy in the context of child vaccine programs in Italy.[31] In the context of COVID-19, studies have found that higher education is associated with higher levels of vaccine acceptance.[8, 29]

Second, we also investigate the role of personal risk-perceptions. Several studies have found that self-perceived risks of COVID-19 positively predicts acceptance of potential COVID-19 vaccines.[19, 27, 29] Likewise, Wong et al. (2020) argued that perceived susceptibility to infection predicted the intention to take a future COVID-19 vaccine.[28] Thus, we expect that personal risk-perception predicts vaccine acceptance.

Collective responsibility is defined as the willingness to protect others by one's own vaccination by means of herd immunity.[9, 32] We consider three groups of predictors to be relevant for this category of vaccine antecedents: (1) prosocial concern (i.e., concern for others), (2) support for pandemic restrictions, and (3) interpersonal trust.

Focusing *first* on prosocial concerns, we measure a range of concerns over the disease's impact on society, including hospitals' ability to help the sick, society's ability to help the disadvantaged, social unrest and crime, and the country's economy. These concerns clearly tap into the collective responsibility and can be expected to positively predict vaccine acceptance given that vaccine uptake can be viewed as a form of other directed behavior that protects individuals beyond the self.

Second, we examine the association between compliance during the COVID-19 pandemic and vaccine acceptance. Protective behavior thus might be viewed as a collective good, implying that compliance with health advice might reflect the willingness to protect others rather than being individually rational to protect oneself.[33] Here, we specifically investigate support for non-pharmaceutical interventions, i.e., government restrictions to stop infection spread as a direct measure of the acceptance of collective responsibility.

Third, interpersonal trust may be a key predictor of the willingness to contribute to collective action during the COVID-19 pandemic.[33] Vaccinations is a form of collective action, where herd immunity is produced via the collective participation in vaccination programs,[34] and people may be more likely to participate if they trust others to do the same.

Table 1, in the measurement section, shows the specific operationalization of each of these predictors and summarizes how these predictors are related to the 5C model. As is evident, we do not include measures that reflect the *calculation* component of the 5C model. From a communication perspective, however, this component is less important as it refers not to the content of the individual's considerations but to more stable individual differences in decision-making style (i.e., extensive cost-benefit analyses of pros and cons of vaccination and infection).[9]

Methods

Patient and public involvement. Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Data. We fielded quota-sampled surveys in eight countries from September 13, 2020 until February 16, 2021: Denmark, Sweden, the United Kingdom, the United States of America, Italy, France, Germany and Hungary (please see Table A1 in the Online Appendix (OA) for an overview of the data collection). These countries were chosen to represent a diversity of national responses to the COVID-19 pandemic as well as a diversity in the severity of the local epidemic. The period consists of eight data rounds in Denmark and seven data rounds in the remaining countries with approximately 500 respondents per data round. In each of the eight countries, the survey company Epinion sampled adult respondents using online panels. Among the panelists invited to take our survey, the response rate across the countries in our sample

was between 18 % (Hungary) and 64 % (the United States). The survey was conducted in accordance with the guidelines of the Danish National Committee of Health Research Ethics for survey research that do not involve human biological material. Survey respondents were quota sampled to match the population margins on age, gender, and geographic location for each of the eight countries. We address imbalances by post-stratifying our sample data to match the demographic margins from the population. All statistical analyses presented in the manuscript employ these post-stratification weights.

Measures

All measures are self-reported from participant questionnaires. The key measures are vaccine acceptance, trust in relevant authorities and groups, disease-specific risk-perceptions, disease-specific attitudes, and propensities to engage in protective behavior. Table 1 provides an overview of question wordings and scales for these measures.

Table 1: Main measures in the study

	Questions	**Values**
Vaccine acceptance	If the health authorities advise people like me to get an approved vaccine against the coronavirus, I will follow their advice.	1. Completely disagree 2. Somewhat disagree 3. Neither agree nor disagree 4. Somewhat agree 5. Completely agree
Confidence	*Trust in health authorities and scientists* How much trust do you have in the following institutions regarding the coronavirus crisis? 1) The national health authorities 2) Scientists	1. Not at all 2. To a lesser degree 3. To a certain degree 4. To a high degree
	Trust in the government Give your assessment on a scale from 0 to 10, where 0 indicates that you have no confidence in the government at all, and 10 indicates that you have full confidence in the government.	0. No confidence at al 1. 2. 3. 4. 5. 6.

		7. 8. 9. 10. Full confidence
	Attitudes To what extent do you agree with the following statements? (1) I'm concerned about my democratic rights in the current circumstances (2) I support the public protests against the government's policies during the COVID-19 pandemic (3) I believe the government is hiding important information from the public about the coronavirus and its cures (4) I have heard or read information about the coronavirus and its cures, which I believe was probably false	1. Completely disagree 2. Somewhat disagree 3. Neither agree nor disagree 4. Somewhat agree 5. Completely agree
	Vote choice What party/who did you vote for in the last general election/presidential election? [date for last election]	[country-specific party/candidate categories]
	Ideology In political matters, people talk of 'the left' and 'the right'. How would you place your views on this scale, generally speaking?	1. The left 2. 3. 4. 5. 6. 7. 8. 9. 10. The right
Constraints	*Fatigue* To what extent do you agree with the following statements? I do not think I can keep up with the restrictions against the coronavirus for much longer.	1. Completely disagree 2. Somewhat disagree 3. Neither agree nor disagree 4. Somewhat agree 5. Completely agree
	Behavior change To what degree do you feel that the current situation with the coronavirus has made you change your behavior to avoid spreading infection?	1. Not at all 2. To a lesser degree 3. To a certain degree 4. To a high degree
	Knowledge	1. Not at all 2. To a lesser degree 3. To a certain degree 4. To a high degree

	To what degree do you feel that you know enough about what you as a citizen should do in relation to the coronavirus?	
Complacency	*Sex* Are you?	1. Male 2. Female
	Age What is your age?	[open textbox]
	Education What is your highest level of completed education?	[country-specific education categories]
	Personal risk-perceptions To what degree are you concerned about the consequences of the corona-virus for you and your family?	1. Not at all 2. To a lesser degree 3. To a certain degree 4. To a high degree
Collective responsibility	*Prosocial concerns* To what degree are you concerned about the consequences of the corona-virus… (1) … for hospitals' ability to help the sick? (2) … for society's ability to help the disadvantaged? (3) … on social unrest and crime? (4) … on the country's economy?".	1. Not at all 2. To a lesser degree 3. To a certain degree 4. To a high degree
	Support for restrictions As you may know, many countries have implemented various measures to stop the spread of the COVID-19 epidemic. We are interested in whether you support or oppose the following measures in your country: (1) Closing of schools and universities (2) Closing (or work from home) for all-but-essential workplaces (e.g. grocery shops, doctors) (3) Cancelling public events (4) Cancelling private gatherings with over 100 people (5) Closing public transportation (6) Ordering people to shelter-in-place (not leaving house with minimal exceptions)	1. Oppose 2. Support

	(7) Restricting internal movement between cities/regions (8) Ordering people to wear face masks in public places (9) Banning arrivals for foreign travelers from some regions.	
	Interpersonal trust Do you think that most people by and large are to be trusted, or that you cannot be too careful when it comes to other people?	0. You cannot be too careful 1. 2. 3. 4. 5. 6. 7. 8. 9. 10. Most people are to be trusted

Notes: Mean and standard deviation of all measures is available in table A2 in the OA.

Vaccine acceptance

Our outcome, vaccine acceptance, is framed as an approved vaccine that is recommended by the national health authorities. This choice reflects that (1) we focus on COVID-19 vaccines specifically, (2) in the context of a global health crisis, where (3) health authorities are emergency approving and very actively encouraging people to take up new vaccines. Some of these important factors are overlooked by previous validated vaccine acceptance measures developed pre-pandemic for measuring attitudes towards vaccines in general. Framing the question in the context of the national health authorities may, however, yield different results than if a standardised and validated measure of vaccine acceptance was used. Furthermore, this choice make it difficult to compare our results with other studies of vaccine acceptance.[9] Although Betsch et al. (2018) recommend to use a general scale, they also acknowledge that this might not be useful when the focus of a study is on a specific vaccine.[9]

Our outcome, vaccine acceptance, is a continuous variable rescaled to range from 0-1, with higher values indicating higher levels of acceptance of a future COVID-19 vaccine.

Predictors of vaccine acceptance

All measures of trust, concern and disease-specific attitudes are treated as continuous variables and rescaled from 0-1, with higher values indicating higher levels of trust, concern and agreement with the disease-specific statements. For our compliance measures, behavior change and knowledge are treated as continuous variables and rescaled to range from 0-1, with higher values indicating higher levels of behavior change and knowledge. Furthermore, we create an index of support for restrictions by adding together the nine measures of support for restrictions. The index is scaled from 0-1, with higher values indicating higher levels of support for restrictions. "Do not know" answers are classified as missing and are not included in the analysis. Sex is an indicator variable (0 for males; 1 for females). Age is a continuous variable rescaled from 0-1 with 0 being the minimum age in the sample (18 years) and 1 being the maximum age (99 years). Education is an indicator variable based on the internationally comparable ISCED-scale (0 for non-tertiary education; 1 for tertiary education). Vote choice is an indicator variable (0 for opposition; 1 for government) (see table A3 in the OA for the coding of this variable). Finally, political ideology is a continuous variable rescaled to range from 0 to 1, with 1 indicating the ideological standpoint to the utmost right.

To ease the interpretation of the results, both the outcome and all predictors are scaled from 0-1 in the analyses below. Table A2 in the appendix reports the descriptive statistics for all the above correlates in our overall sample. Moreover, Figure A1 in the appendix shows an overview of all bivariate correlations.

Statistical analyses

Since our dependent variable, vaccine acceptance, is continuous, we use OLS regression models to investigate the individual-level predictors of vaccine acceptance. In the results section we present two models: (I) a model with all the bivariate correlations of vaccine acceptance, (II) a full model that includes all predictors described above. Model II includes country dummies to control away country specific effects. Thus, our aim is to identify individual-level predictors of acceptance of a COVID-19 vaccine. To account for the fact that individuals are nested within countries, we cluster the standard errors at the country level.

In the OA we conduct a range of sensitivity analyses that probe the robustness of our benchmark results. First, we replicate the main analyses while treating the 4-point scale

measures of trust, concern, behavior change and knowledge as categorical variables instead of continuous (see Figure A4-A7 in the OA). Second, we similarly replicate the analyses while using a dichotomous - rather than the continuous - coding of the outcome[1] (see Figure A8 in the OA). Third, the present results reflect the analysis period between September 13, 2020 and February 16, 2021. Thus, we include data both pre- and post-approval of the COVID-19 vaccines. In the OA, we compare the results before and after COVID-19 vaccines were approved (see Figure A9 in the OA). Fourth, in some contexts - most notably the countries with federal states (the US and Germany) in our sample - much of the COVID-19 response is done on a regional level. To account for state-specific heterogeneity, we analyze the individual-level predictors separately in Germany and the US, while controlling for state rather than country level dummies (see Figure A10-A12 in the OA). The results are essentially similar to those presented in the main text.

Results

Figure 1 shows the development in vaccine acceptance, by country. For the descriptive analyses below, we refer to the percentage who accept the vaccine (i.e. share of respondents who answered "Somewhat agree" or "Completely agree" to whether they will follow the advice of the health authorities and get an approved vaccine). This percentage refers to the level of vaccine acceptance for the full analysis period, i.e. September 2020 - February 2021.

[Figure 1 about here]

Across the eight countries, we observe large differences in the level of vaccine acceptance. Specifically, we observe the highest level of vaccine acceptance in Denmark (82 %). Furthermore, we observe a high level of vaccine acceptance in the United Kingdom (76 %). However, we observe only moderate levels of vaccine acceptance in Sweden (67 %), Germany (66 %), Italy (66 %), and the United States (61 %). The lowest levels of vaccine acceptance is observed in France (55 %) and Hungary (52 %). However, it is worth noticing that in most of

[1] For the dichotomous outcome measure, respondents who answered "Somewhat agree" or "Completely agree" are coded as 1, indicating vaccine acceptance.

the countries, we observe increasing levels of vaccine acceptance over the course of the pandemic as COVID-19 vaccines are being approved and rolled out.

The results indicate that vaccine skepticism is present in most of the countries in our sample. These results underscore two important points. First, the presence of vaccine skepticism demonstrates the importance of understanding the individual-level variation of vaccine acceptance in order to understand the targets of health communication. Second, the large variation across countries emphasizes the need of a more thorough understanding of the importance of national context. In the Discussion section, we therefore move beyond the individual-level focus to also exploring macro-level correlations of vaccine acceptance.

On this basis, we turn towards understanding the individual-level predictors of acceptance of a COVID-19 vaccine. Figure 2 presents the results of the analyses (see Table A4 in the OA). In the discussions of results below, we specifically focus on the estimated correlations from model II in table A4 (the full model). The size of the estimated coefficients reported below reflects the difference in vaccine acceptance when we compare individuals at the minimum and maximum values, respectively, for each of the correlates.

[Figure 2 about here]

Examining the *confidence* predictors, we observe that trust in the health authorities and trust in scientists are the strongest predictors of vaccine acceptance. Respondents who have the highest level of trust in the national health authorities have 17 (95% CI 14-20) percentage points higher acceptance of a COVID-19 vaccine compared to those with the least trust. The same pattern is observed for trust in scientists. Respondents with the highest level of trust have 21 (95% CI 16-26) percentage points higher acceptance of an approved COVID-19 vaccine compared to those with the lowest trust level. Furthermore, trust in the government is also significantly positively predicting vaccine acceptance. Respondents high in government trust have 5 (95% CI 0-10) percentage points higher acceptance of an approved COVID-19 vaccine compared to those with the lowest level of trust. Focusing on the attitudinal aspect of *confidence* predictors, we observe that conspiracy beliefs significantly negatively predict vaccine acceptance, while awareness of misinformation significantly positively predicts vaccine acceptance. Specifically, respondents who score highest in thinking that the government is hiding information about the

coronavirus and its cures (conspiracy beliefs), have 9 (95% CI 5-12) percentage points higher acceptance of an approved COVID-19 vaccine compared with those who do not subscribe to conspiracies. Respondents who think that they have been exposed to misinformation have 4 (95% CI 1-7) percentage points higher acceptance of an approved COVID-19 vaccine. Both concern about democratic rights and support for protests are negatively, but not significantly, associated with vaccine acceptance. Finally, neither political ideology nor vote choice are significantly associated with vaccine acceptance.

Moving to the *constraints* predictors, we observe that behavior change is a significant positive predictor of vaccine acceptance. Specifically, respondents who have changed their behavior the most to avoid spreading infection have 11 (95% CI 7-14) percentage points higher acceptance of an approved COVID-19 vaccine compared to respondents who have changed their behavior the least. Neither fatigue nor knowledge are significant predictors of vaccine acceptance.

Focusing on the *complacency* predictors, we observe that being male, older, and having tertiary education is associated with higher vaccine acceptance. Specifically, females have 5 (95% CI 3-7) percentage points lower acceptance of an approved vaccine compared to males. Age positively predicts vaccine acceptance: When comparing respondents at the minimum and maximum level of age in the sample (18-99 years), the difference is 19 (95% CI 12-26) percentage points. Furthermore, respondents with tertiary education have 2 (95% CI 1-3) percentage points higher acceptance of an approved COVID-19 vaccine compared to respondents with non-tertiary education. Finally, personal risk-perception is also a positive predictor of vaccine acceptance. The respondents who are the most concerned about the consequences of the corona crisis for themselves and their families have 9 (95% CI 3-14) percentage points higher acceptance of an approved COVID-19 vaccine compared to the least concerned.

Finally, looking at the *collective responsibility* predictors, the strongest predictors of vaccine acceptance is support for restrictions. Specifically, respondents who are most supportive of restrictions have 13 (95% CI 9-17) percentage points higher acceptance of an approved vaccine compared to respondents who are the least supportive of restrictions. Furthermore, interpersonal trust positively predicts vaccine acceptance. Respondents with the highest level of interpersonal trust have 6 (95% CI 3-9) percentage points higher acceptance of an approved COVID-19 vaccine compared to respondents with the lowest interpersonal trust level. Concern

for the capacity of hospitals is also a positive predictor of vaccine acceptance. Comparing those who are the most concerned for the capacity of hospitals to those who are the least concerned shows a 5 (95% CI 2-8) percentage points increase in vaccine acceptance. Additionally, concern for social unrest and crime negatively predicts vaccine acceptance. Comparing those who are the most concerned for social unrest and crime to those who are the least concerned shows a 3 (95% CI 1-5) percentage points decrease in vaccine acceptance. Finally, neither concern for the society's ability to help the disadvantaged nor concern for the country's economy are significantly associated with vaccine acceptance.

The relationship between the predictors and vaccine acceptance is essentially the same across the bivariate and the full model. However, ideology changes from being significant and negative in the bivariate model to insignificant and positive in the full model. Furthermore, concern for the society's ability to help the disadvantaged changes from being significant and positive in the bivariate model to insignificant and negative in the full model. Overall, the empirical patterns are relatively stable across countries, but we do observe some notable cross-country differences with respect to specific predictors (see Figure A2 in the OA). In Denmark, neither trust in scientists nor personal risk-perceptions are significant predictors of vaccine acceptance. Focusing on heterogeneity across individual-level demographic subgroups, we see that results are essentially homogenous across sex, age and educational level (see Figures A13-A15 in the OA). Even though the levels of vaccine acceptance has changed over the course of the pandemic, the results of the individual-level predictors of vaccine acceptance are essentially the same when results pre- and post-approval of COVID-19 vaccines are compared (see Figure A9 in the OA).

Discussion

In this paper, we investigated (1) the level of vaccine acceptance of an approved COVID-19 vaccine, and (2) individual-level predictors of vaccine acceptance. While levels of vaccine acceptance generally increased when COVID-19 vaccines were approved during the winter of 2020-2021, the results also demonstrate that for many of the countries in our sample, people are only moderately willing to receive a vaccine. This highlights the need for understanding the individual-level variation underlying vaccine skepticism and identifying potential targets for guiding health communication to increase vaccine acceptance.

The analyses of individual-level predictors demonstrate that the key drivers of COVID-19 vaccine acceptance are (1) trust in the national health authorities and scientists, and (2) personal health concerns. These results are consistent with findings of similar studies that emphasize that those who have more trust in experts and scientists are more willing to vaccinate.[13, 35] Likewise, several studies have also found personal risk-perception to be an important predictor of acceptance of a COVID-19 vaccine.[20, 27, 29, 36] Furthermore, Neumann-Böhme & Sabat (2020) find that the most frequently used reason for vaccination is to protect the respondents own and family members health.[37] Motta et al. (2020) also find that messages emphasizing the personal risks at failing to vaccinate are effective in convincing people to plan to get vaccinated.[38] Thus, in the framework of the 5C Model from Betsch et al. (2020), skepticism towards a COVID-19 vaccine primarily results from *complacency* or a lack of *confidence*.[9] Using these insights is essential to guide health communication in a way that can potentially increase vaccine acceptance.[39] Specifically, our findings suggest that efforts should be focused on motivating the complacent, i.e. those who lacks concerns about the personal consequences of the pandemic. This can be done through informational interventions to explain disease risks and stress the social benefits of vaccination.[39] When it comes to individuals with a lack of confidence, they usually possess a considerable amount of incorrect knowledge that distorts risk perceptions and undermines the general trust in vaccination.[39] Consistent with this, the present findings also highlight conspiracy beliefs as a key predictor of vaccine hesitancy. Following Betsch et al. (2015), this implies that interventions aiming at debunking myths is the key to increase vaccine acceptance among those who lack confidence.[39] However, strategies aiming at those who lack confidence are scarce, thus, focusing on motivating the complacent may be more effective.[39] Altogether, these results suggest that the most important communication targets are the consequences of infections for the self and close others and debunking of myths.

While trust in the national health authorities and scientists are the most prominent factors together with personal risk-perceptions when everything is assessed individually, the data also shows that vaccine skepticism during the pandemic is interwoven into a larger web of attitudes and behaviors related to anti-systemic sentiments. Hence, in addition to trust in health authorities, a lack of vaccine acceptance was also related to endorsement of conspiracy beliefs, support for other non-pharmaceutical interventions, and a lack of compliance with advice about changing behavior to avoid spreading infections.

As a final explorative analysis, we therefore assess whether the highlighted factors also help explain the cross-national variation in vaccine acceptance. To this end, we examine the correlations between vaccine acceptance at the national level and each of the different independent measures aggregated for each country. All of these correlations are available in Figure A16 in the OA. In Figure 3, we present the correlations for key variables highlighted above: Trust in health authorities, personal risk-perceptions, conspiracy beliefs and behavior change. While the analysis is highly limited by the fact that it only includes eight national cases, it is nonetheless strikingly informative. While differences in personal risk-perceptions are not strongly related to cross-national differences, country averages in the anti-systemic measures, especially (lack of) trust in health authorities, are exceptionally closely related to country averages in vaccine acceptance. Trust in health authorities does not just explain differences in vaccine acceptance between individuals but also between countries.

[Figure 3 about here]

In sum, these analyses point to the significant challenges involved in convincing vaccine skeptics. The web of anti-systemic attitudes and distrust that vaccine skepticism is interwoven in makes it difficult to craft efficient health communication, as the effectiveness of communication is fundamentally contingent on the preceding existence of trust in its source. This challenge might be further deepened during the COVID-19 pandemic as research suggests that the stress of the pandemic and the restrictions itself fuels anti-systemic beliefs.[40] The results thus, first, emphasize the general importance of building trust prior to the onset of crises and of investing significant resources into maintaining trust as a crisis unfolds.[41] Second, for most short-term oriented communication purposes, the results suggest that the best communication targets are the consequences of infections for the self and close others and debunking of myths.

The results should however be considered in the light of the following limitations. First, the results are based on observational data which limits causal traction. Second, we investigate self-reported vaccine acceptance, and thus, not actual vaccination behavior. Therefore, we cannot be sure that acceptance of the vaccine translates into actual vaccination rates, since self-reported vaccine acceptance can be subject to social desirability bias.

Conclusion

The results demonstrate that vaccine skepticism is present in most of the countries in our sample, even after vaccines have been approved. Consistent with similar studies, the analyses of the individual-level predictors show that the key individual drivers of acceptance of an approved COVID-19 vaccine are (1) trust in the national health authorities and scientists, and (2) personal health concerns. The results suggest that an important communication target is the consequences of infections for the self and close others. Furthermore, these results emphasize that anything that erodes trust in health authorities and scientists are problematic for vaccination efforts, and thus, underscore the key importance of health and political authorities to strive to uphold trust to the maximum extent during the pandemic. This is not just crucial for managing the pandemic here and now but also as a preparation for the next health emergency.

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Figure captions and legends

Figure 1: Development in vaccine acceptance for an approved COVID-19 vaccine

Note: N = 18,231. The figure illustrates the development in vaccine acceptance across countries. Vaccine acceptance is here defined as the proportion who answers "Somewhat agree" or "Completely agree" to the question: "If the health authorities advise people like me to get an approved vaccine against the coronavirus, I will follow their advice."

Figure 2: Individual-level correlations of vaccine acceptance

Note: N = 18,231. Black circles are the estimated correlations based on model I-II in Table A4 in the OA. Model II includes control for country dummies. Horizontal bars are the associated 95 % confidence interval.

Figure 3: Macro-level correlations of vaccine acceptance

Note: The figure plots country averages for vaccine acceptance and country averages for four measures: Trust in health authorities, egotropic concern related to COVID-19, endorsement of COVID-19 conspiracy beliefs and the degree of changed behavior to avoid spreading infections during the COVID-19 pandemic. Reported correlations are pearson's r.

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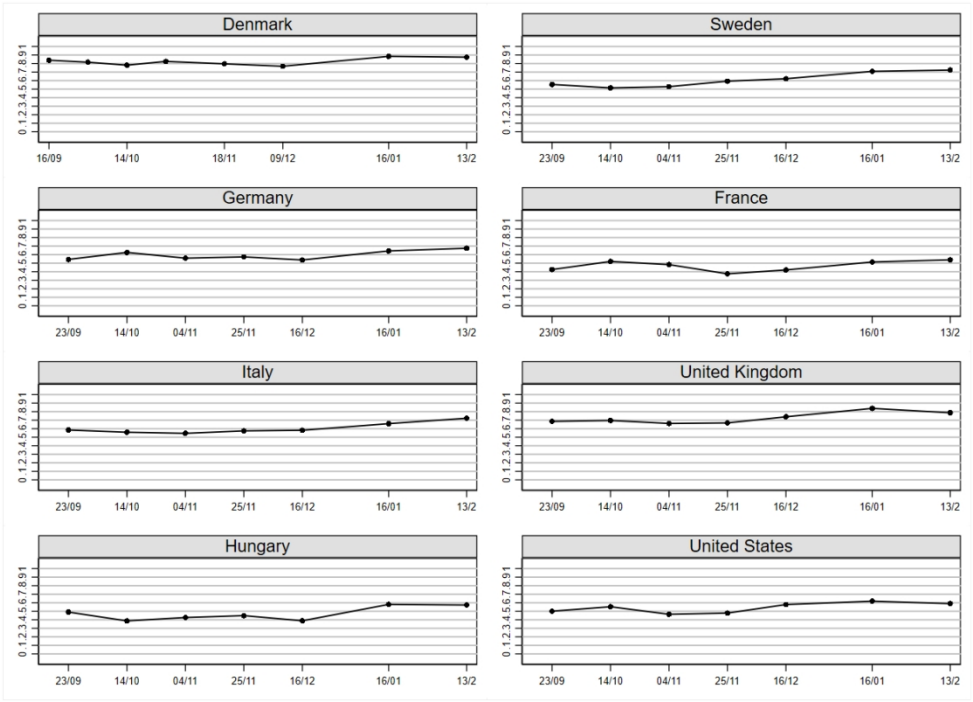

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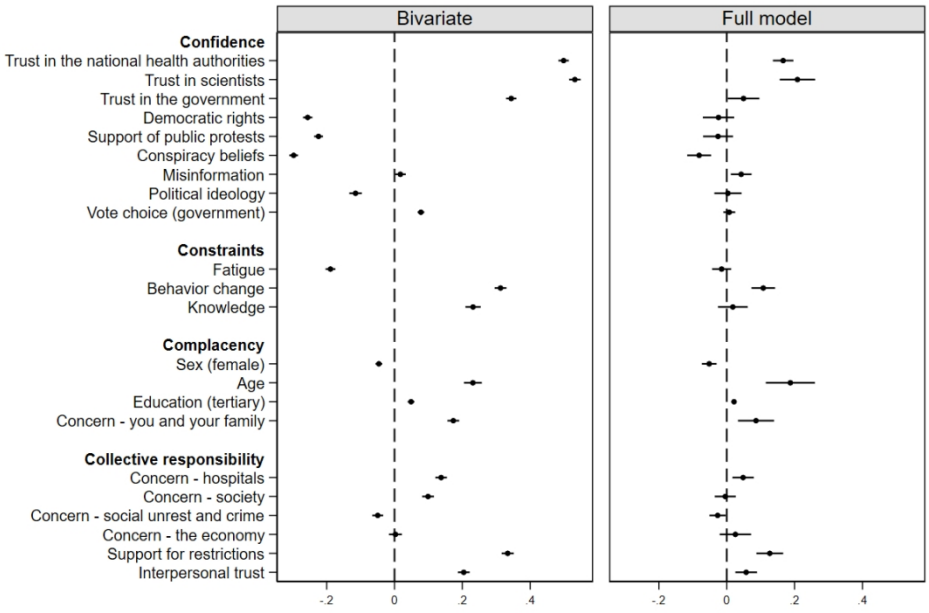

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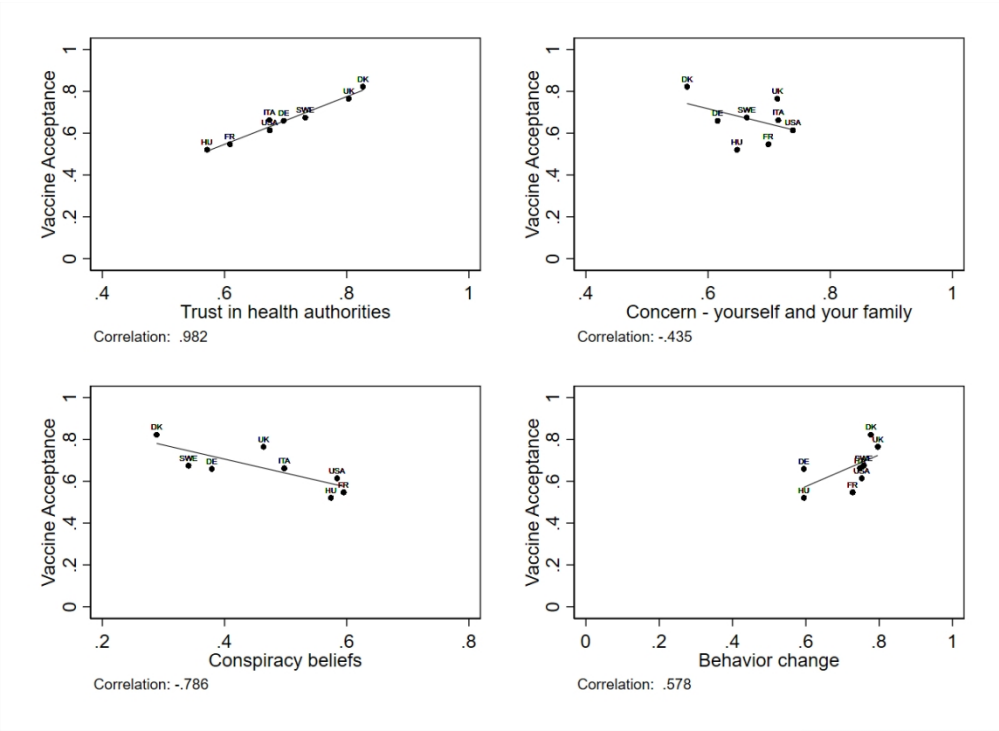

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Table A1: Overview of data collection

Country	Dates	Obs.
Denmark	September 13, 2020 – February 16, 2021	2,765
Sweden	September 20, 2020 – February 16, 2021	2,149
United Kingdom	September 20, 2020 – February 16, 2021	2,437
United States	September 20, 2020 – February 16, 2021	2,185
Italy	September 20, 2020 – February 16, 2021	2,411
France	September 20, 2020 – February 16, 2021	2,090
Germany	September 20, 2020 – February 16, 2021	2,380
Hungary	September 20, 2020 – February 16, 2021	1,814

Table A2: Descriptive statistics

	Mean	SD	Min	Max	N
Vaccine acceptance	0.66	0.34	0	1	18,231
Confidence					
Trust in national health authorities	0.70	0.29	0	1	18,231
Trust in scientists	0.76	0.26	0	1	18,231
Trust in the government	0.54	0.31	0	1	18,231
Concern about democratic rights	0.47	0.35	0	1	18,231
Support for protests	0.36	0.36	0	1	18,231
Conspiracy beliefs	0.46	0.36	0	1	18,231
Misinformation	0.60	0.31	0	1	18,231
Political ideology	0.50	0.26	0	1	18,231
Vote choice (government)	0.47	0.50	0	1	18,231
Constraints					
Fatigue	0.37	0.33	0	1	18,231
Behavior change	0.73	0.27	0	1	18,231
Knowledge	0.80	0.22	0	1	18,231
Complacency					
Sex (female)	0.46	0.50	0	1	18,231
Age	0.35	0.18	0	1	18,231
Education (tertiary)	0.50	0.50	0	1	18,231
Concern - you and your family	0.67	0.28	0	1	18,231
Collective responsibility					
Concern - hospitals	0.71	0.29	0	1	18,231
Concern - society	0.69	0.28	0	1	18,231
Concern - social unrest and crime	0.63	0.31	0	1	18,231
Concern - the country's economy	0.78	0.26	0	1	18,231
Support for restrictions	0.69	0.27	0	1	18,231
Interpersonal trust	0.50	0.28	0	1	18,231

Table A3: Coding of vote choice variable

Country	Government	Opposition
Denmark	Socialdemokratiet	Konservative
	Radikale	Nye Borgerlige
	Socialistisk Folkeparti	Klaus Riskjær Pedersen
	Enhedslisten	Liberal Alliance
		Kristendemokraterne
		Dansk Folkeparti
		Stram Kurs
		Venstre
		Alternativet
Sweden	Miljöpartiet	Kristendemokraterna
	Socialdemokraterna	Moderaterna
	Vänsterpartiet	Sverigedemokraterna
	Centerpartiet	
	Liberalerna	
United Kingdom	Conservative	Labour
		SNP
		Liberal Democrats
United States	Republicans	Democrats
Italy	Centre-Left	Centre-Right
	Five Star Movement	Free and Equal
France	Macron	Fillon
		Le Pen
		Dupont-Aignan
		Hamon
		Melenchon
Germany	CDU/SDU	AfD
	SPD	FDP
		Die Linke
		Grüne
Hungary	Fidesz-KDNP	Jobbik
		MSZP-MM
		LMP
		DK
		MM

Figure A1: Bivariate correlations

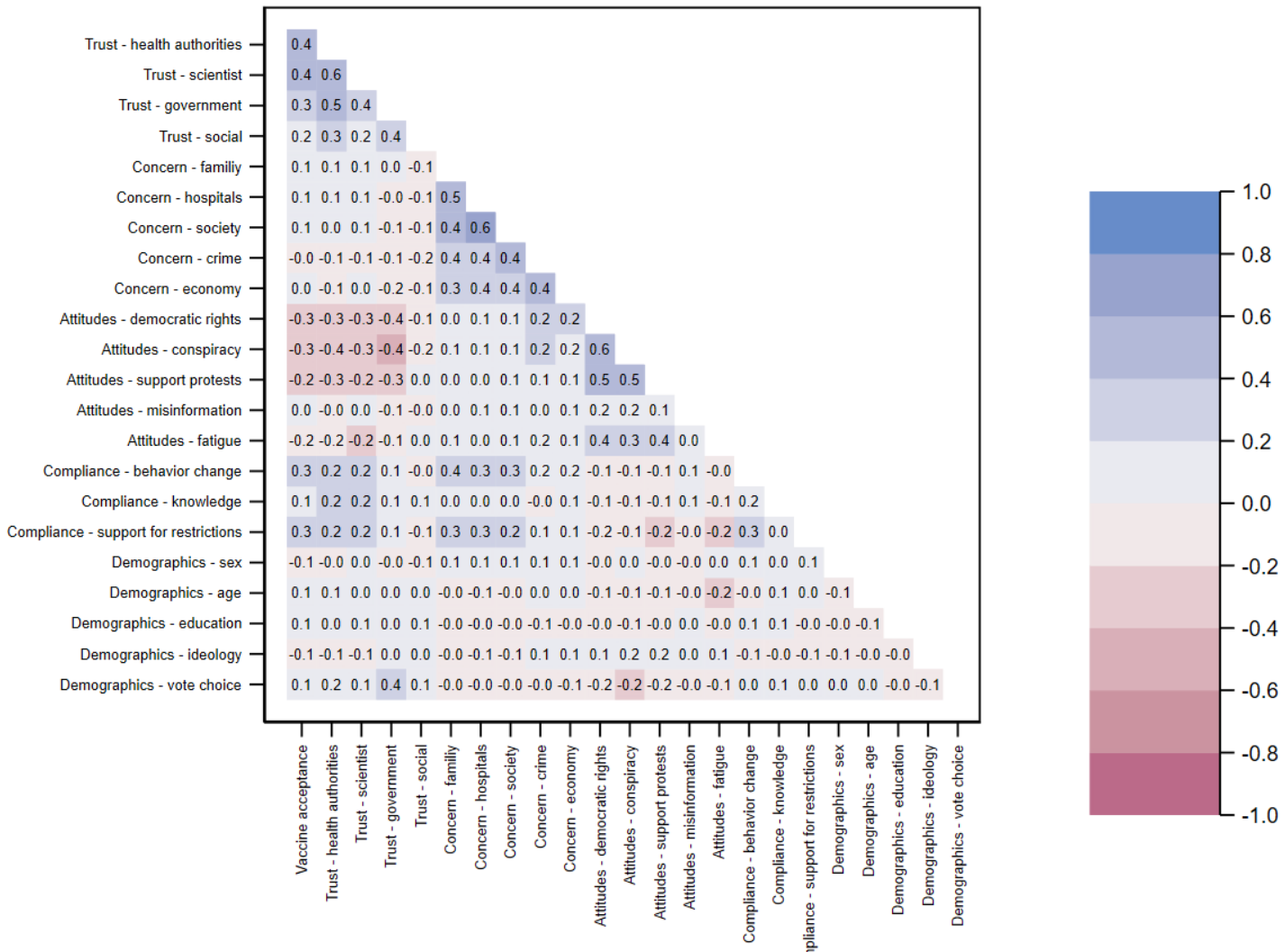
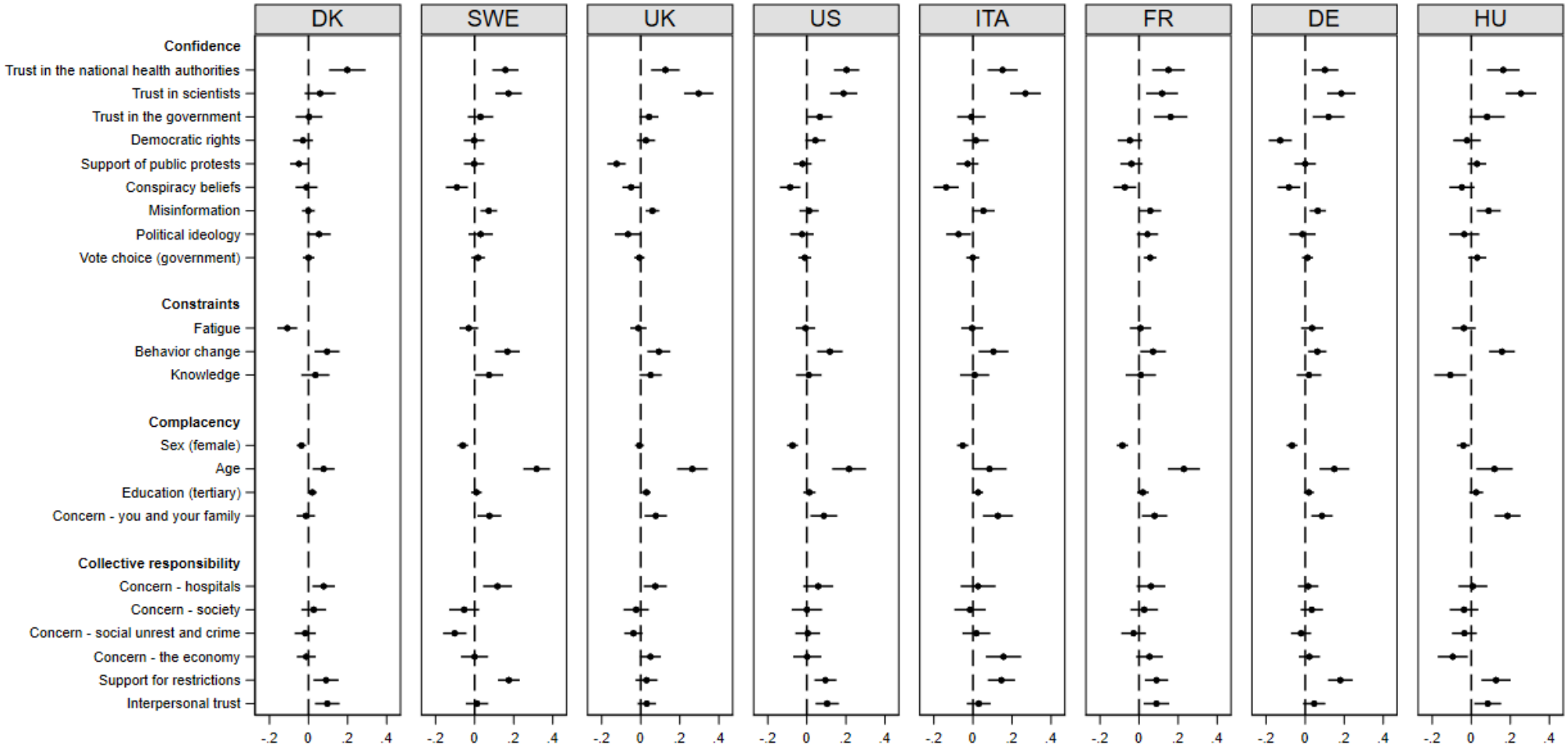


Table A4: Individual-level predictors of vaccine acceptance

	Model I Bivariate		Model VI Full model	
Confidence				
Trust in health authorities	0.498***	(0.008)	0.166***	(0.013)
Trust in scientists	0.531***	(0.009)	0.208***	(0.022)
Trust in the government	0.344***	(0.008)	0.050*	(0.020)
Concern about democratic rights	-0.256***	(0.007)	-0.024	(0.020)
Support for protests	-0.224***	(0.007)	-0.026	(0.019)
Conspiracy beliefs	-0.297***	(0.007)	-0.081***	(0.015)
Misinformation	0.017*	(0.008)	0.043*	(0.013)
Ideology	-0.115***	(0.009)	0.004	(0.017)
Vote choice (government)	0.078***	(0.005)	0.008	(0.007)
Constraints				
Fatigue	-0.189***	(0.007)	-0.015	(0.012)
Behavior change	0.312***	(0.009)	0.108***	(0.015)
Knowledge	0.232***	(0.011)	0.018	(0.019)
Complacency				
Sex (female)	-0.046***	(0.005)	-0.052***	(0.009)
Age	0.231***	(0.013)	0.188***	(0.031)
Education (tertiary)	0.049***	(0.005)	0.022***	(0.002)
Concern - you and your family	0.173***	(0.009)	0.086**	(0.023)
Collective responsibility				
Concern - hospitals	0.137***	(0.009)	0.048**	(0.013)
Concern - society	0.099***	(0.009)	-0.004	(0.013)
Concern - social unrest and crime	-0.049***	(0.008)	-0.027*	(0.010)
Concern - the country's economy	0.003	(0.010)	0.026	(0.020)
Support for restrictions	0.334***	(0.009)	0.127***	(0.017)
Interpersonal trust	0.204***	(0.009)	0.057**	(0.014)
Constant			-0.034	(0.025)
Observations	18,231		18,231	
R^2	NA		0.322	

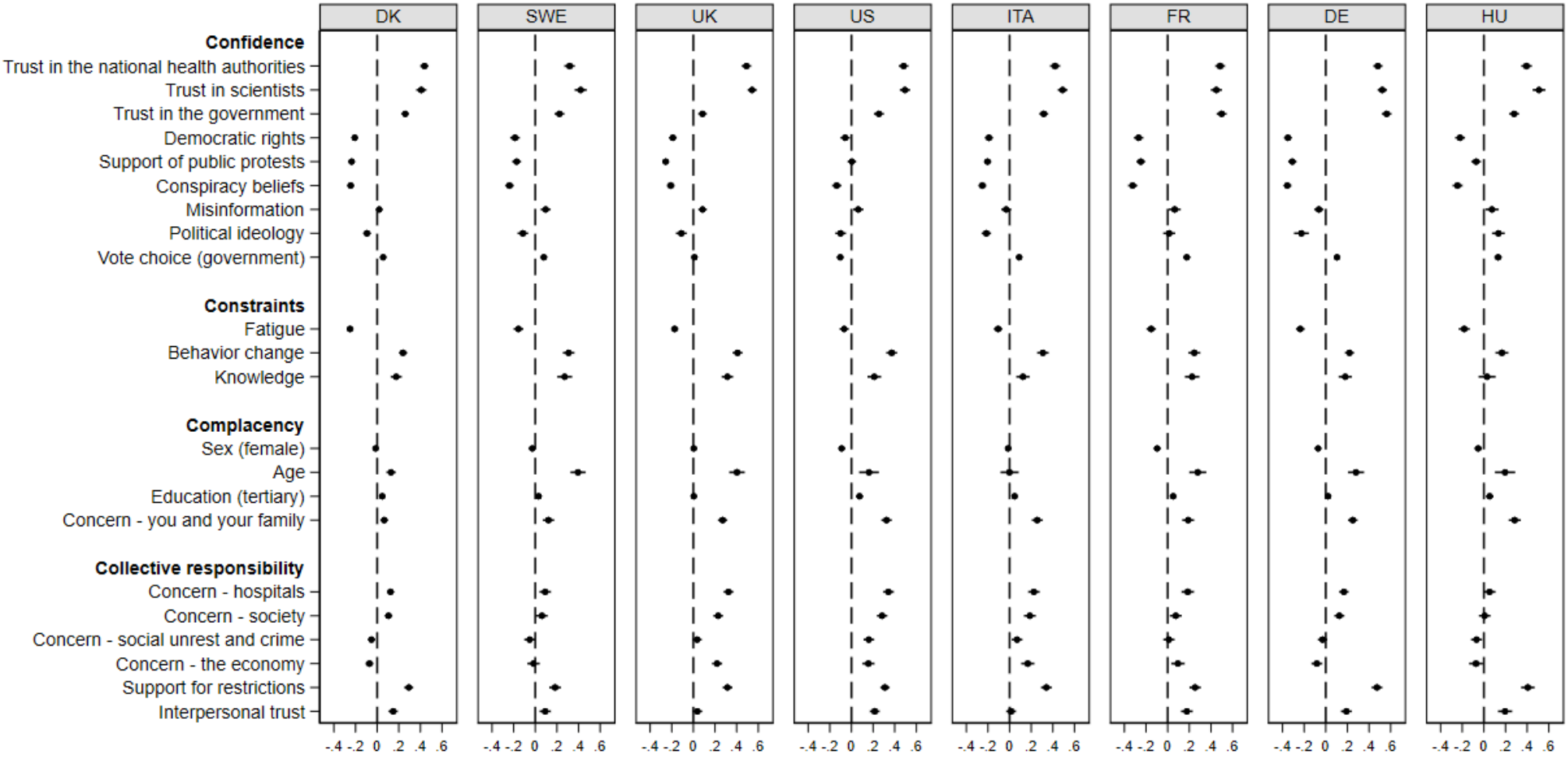
Notes. Entries are unstandardized OLS regression coefficients from models with all variables standardized on a scale from 0-1. Clustered robust standard errors on country level in parentheses. Model 1 displays effects from bivariate models and, hence, a combined R^2 cannot be computed. Model II includes control for country dummies. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Figure A2: Individual-level correlations of vaccine acceptance by country



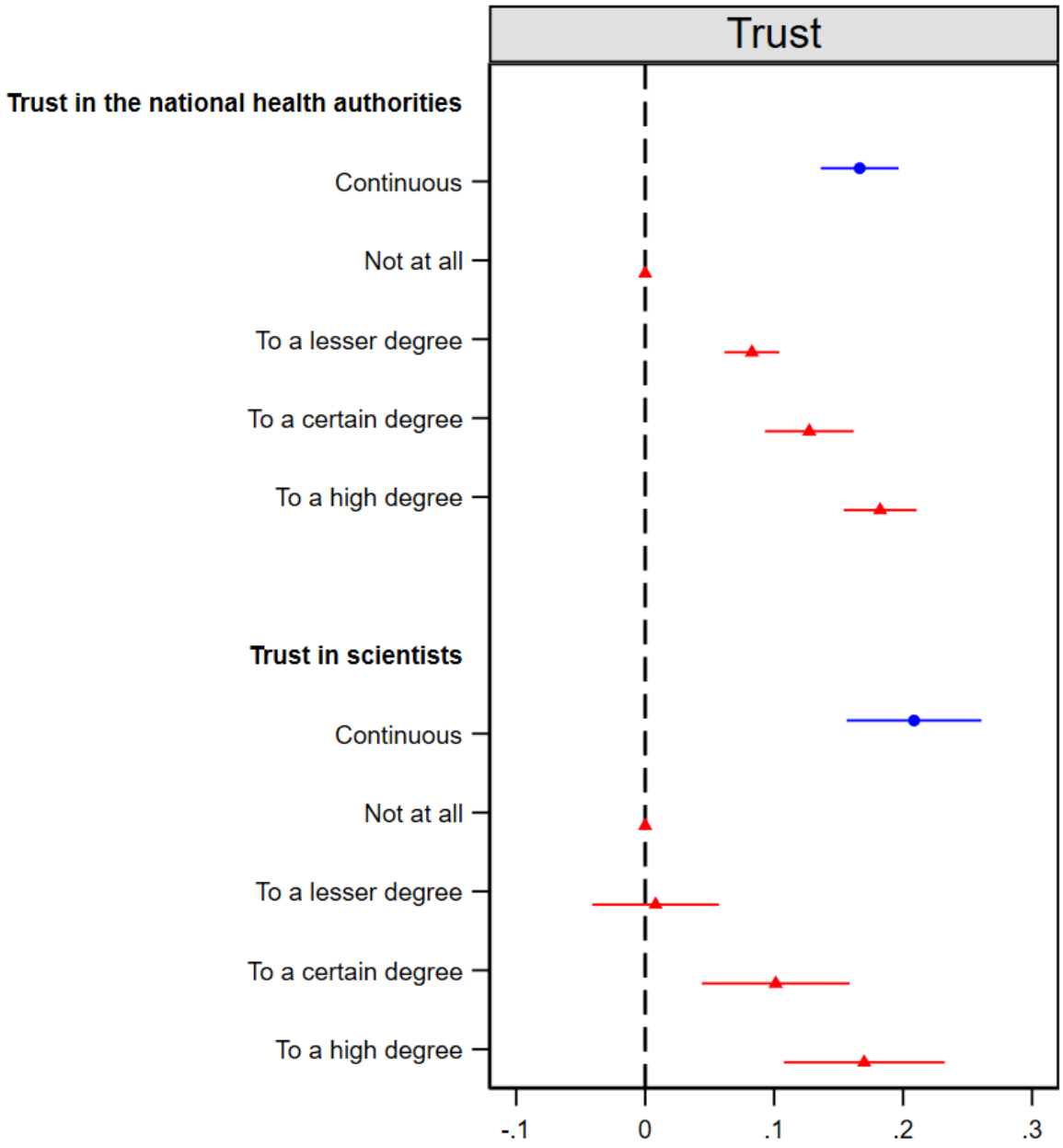
Note: N = 18,231. Black circles are the estimated correlations. Horizontal bars are the associated 95 % confidence intervals.

Figure A3: Bivariate correlations by country



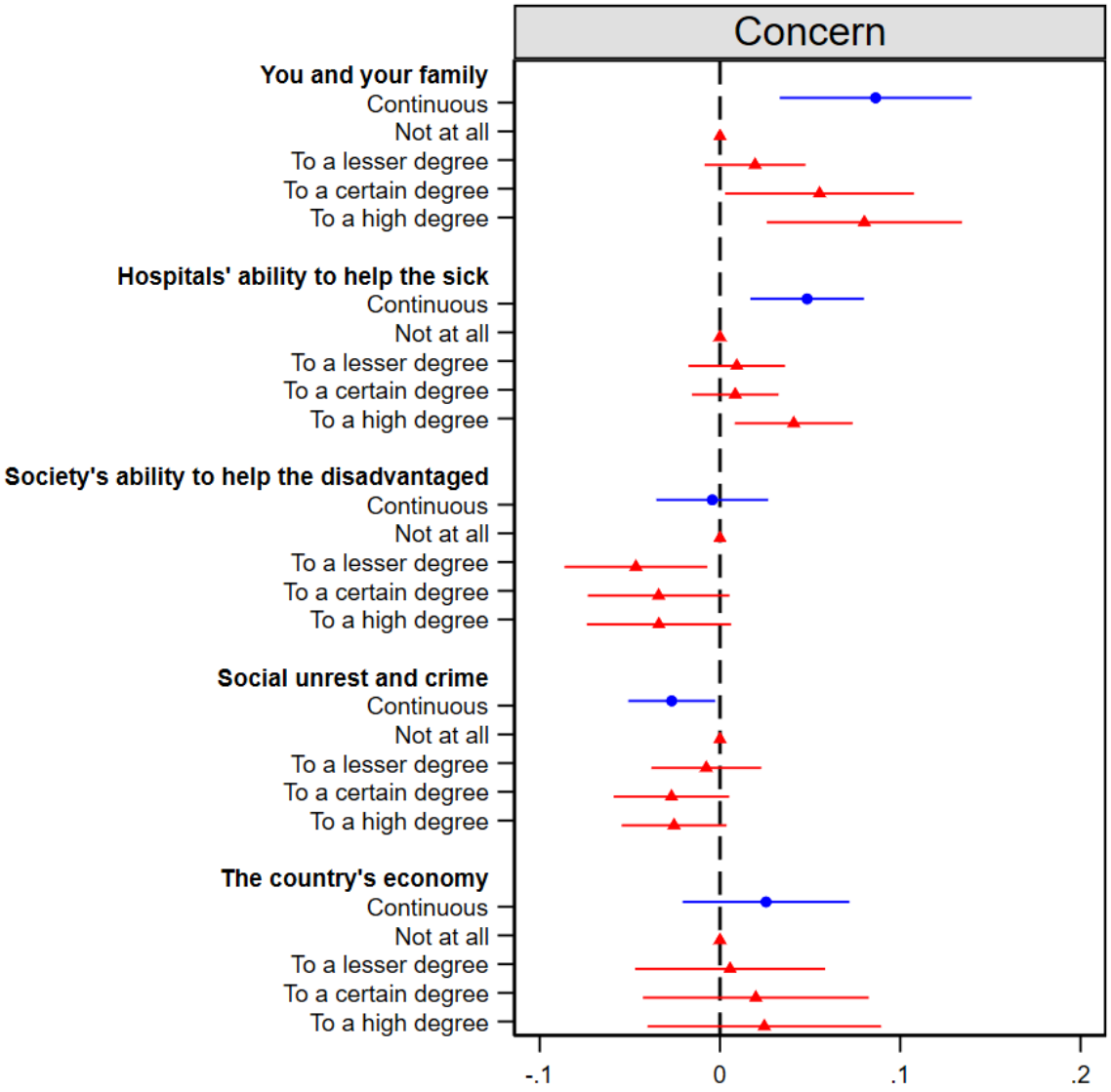
Note: N = 18,231. Black circles are the estimated bivariate correlations. Horizontal bars are the associated 95 % confidence intervals.

Figure A4: Replicating the analysis with categorical trust variables



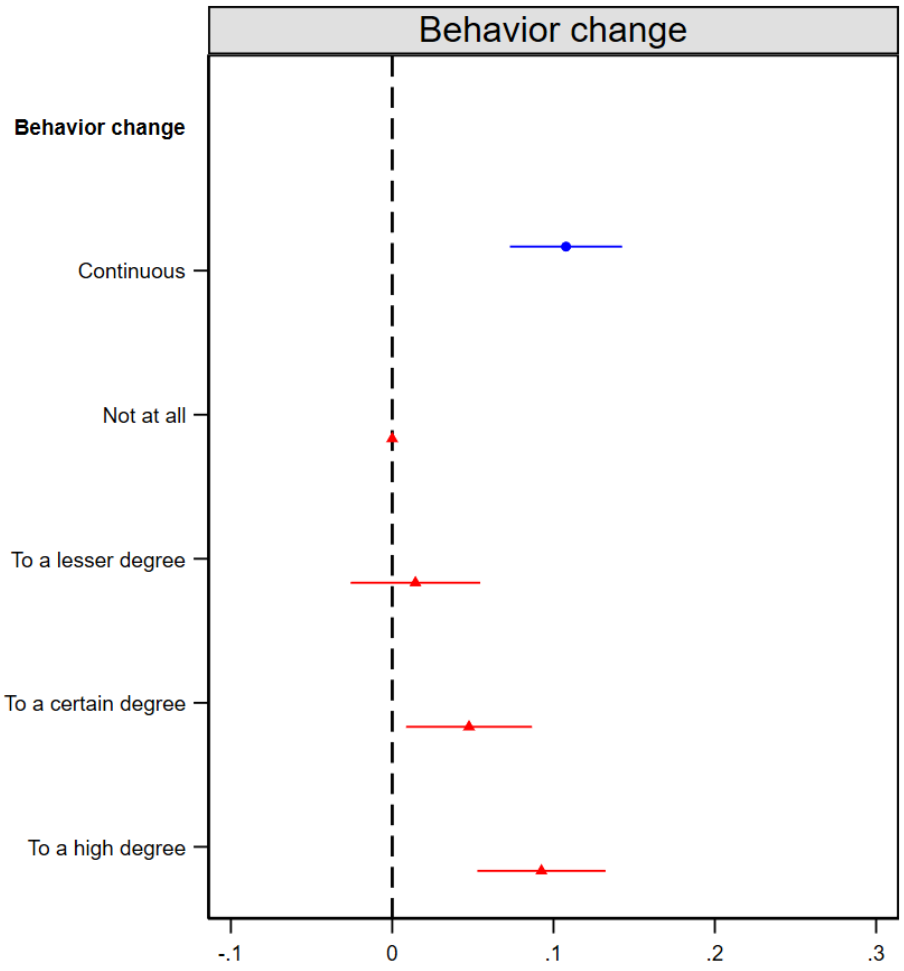
Note: N = 18,231. Blue circles are the estimated correlations based on model II in Table A4 (continuous trust variables). Red triangles are the estimated correlations based on the same model, using categorical trust variables instead. Both models include control for country dummies. Horizontal lines are the associated 95 % confidence intervals.

Figure A5: Replicating the analysis with categorical concern variables



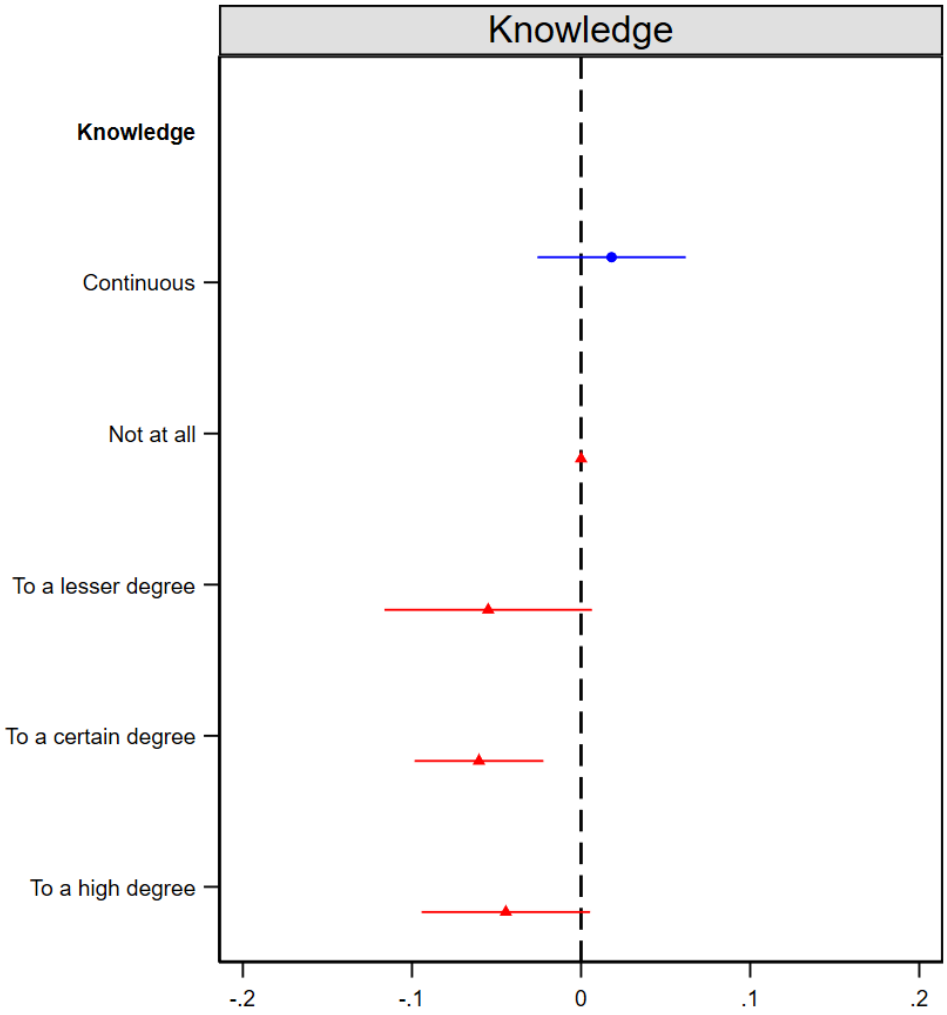
Note: N =18,231. Blue circles are the estimated correlations based on model II in Table A4 (continuous concern variables). Red triangles are the estimated correlations based on the same model, using categorical concern variables instead. Both models include control for country dummies. Horizontal lines are the associated 95 % confidence intervals.

Figure A6: Replicating the analysis with a categorical behavior change variable



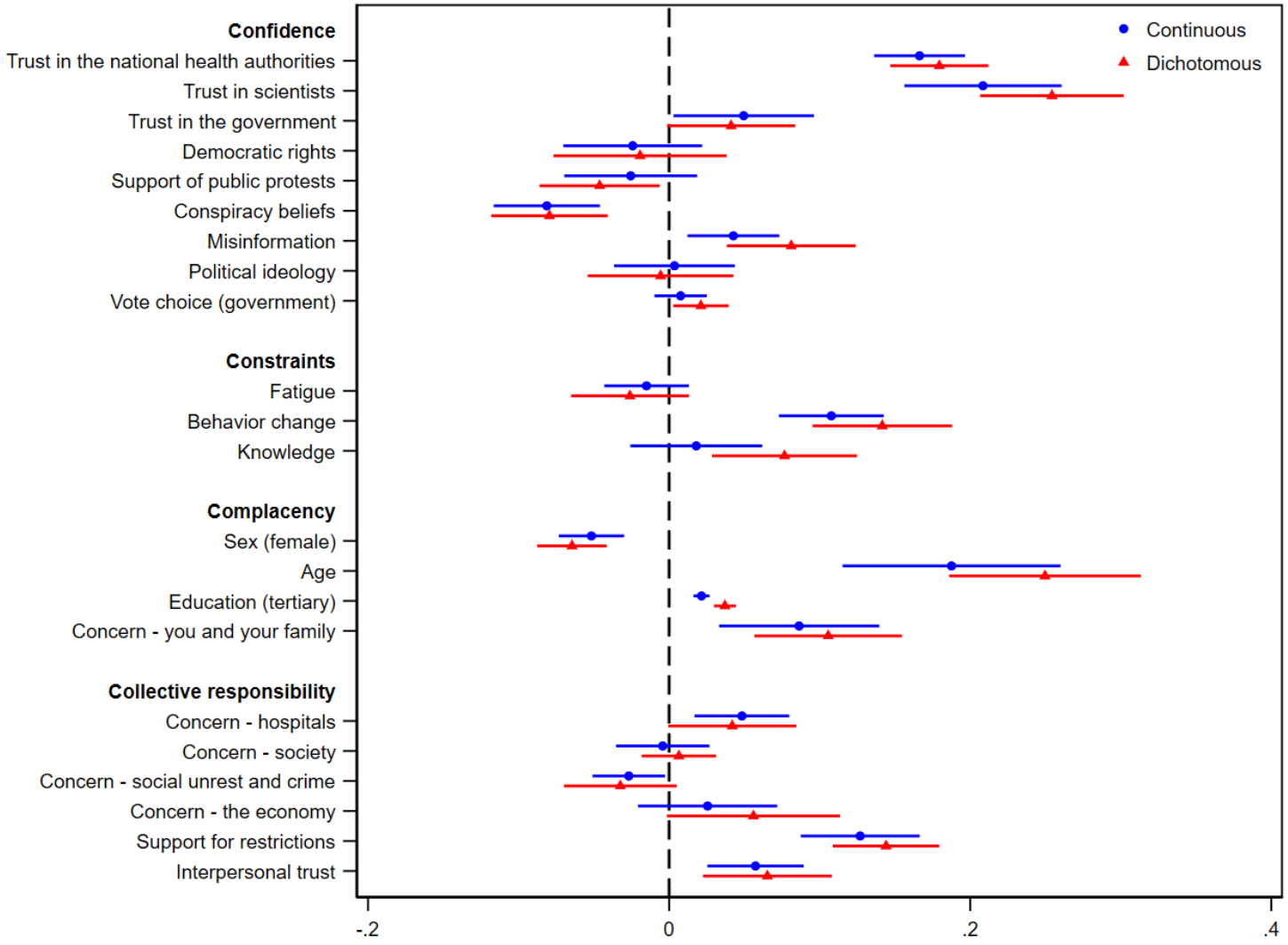
Note: N = 18,231. Blue circles are the estimated correlations based on model II in Table A4 (continuous behavior change variable). Red triangles are the estimated correlations based on the same model, using a categorical behavior change variable instead. Both models include control for country dummies. Horizontal lines are the associated 95 % confidence intervals.

Figure A7: Replicating the analysis with a categorical knowledge variable



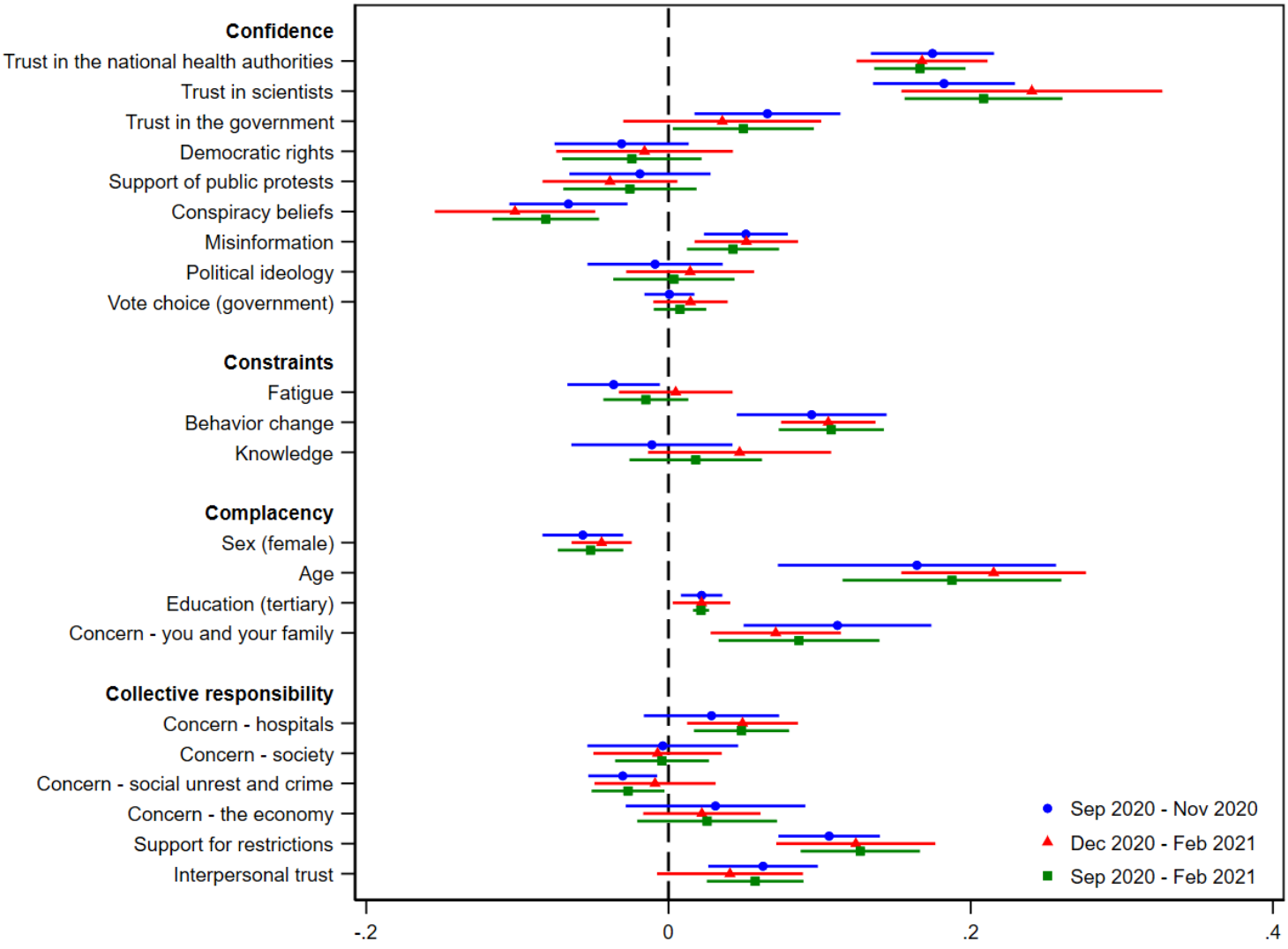
Note: N = 18,231. Blue circles are the estimated correlations based on model II in Table A4 (continuous knowledge variable). Red triangles are the estimated correlations based on the same model, using a categorical knowledge variable instead. Both models include control for country dummies. Horizontal lines are the associated 95 % confidence intervals.

Figure A8: Replicating the analysis with a dichotomous vaccine acceptance outcome



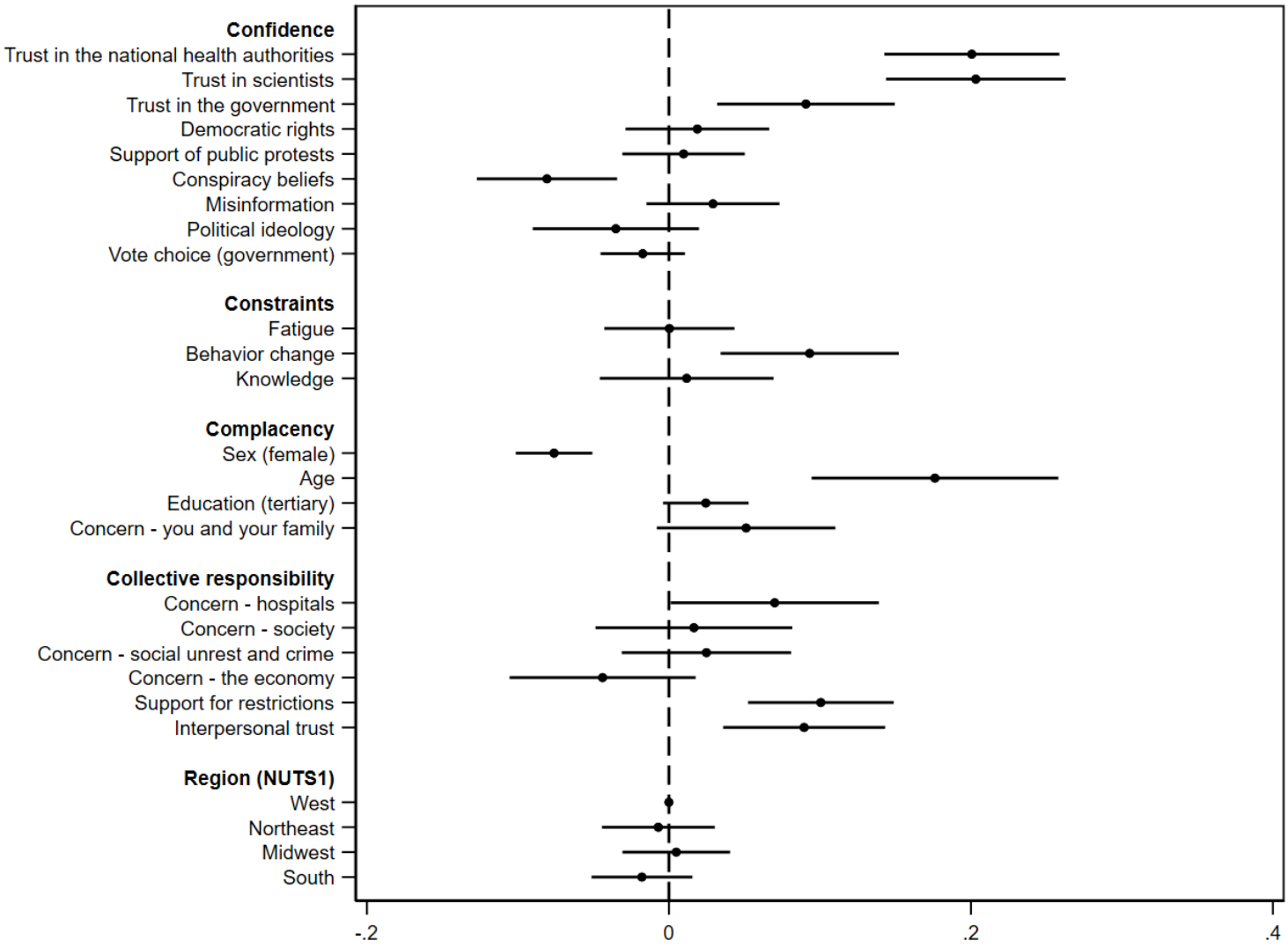
Note: N = 18,231. Blue circles are the estimated correlations based on model II in Table A4 (continuous outcome). Red triangles are the estimated correlations based on the same model, using a dichotomous measure of vaccine acceptance instead (with "somewhat agree" and "completely agree" taking the value 1, indicating vaccine acceptance). Both models include control for country dummies. Horizontal lines are the associated 95 % confidence intervals.

Figure A9: Comparing results before and after approval of COVID-19 vaccines



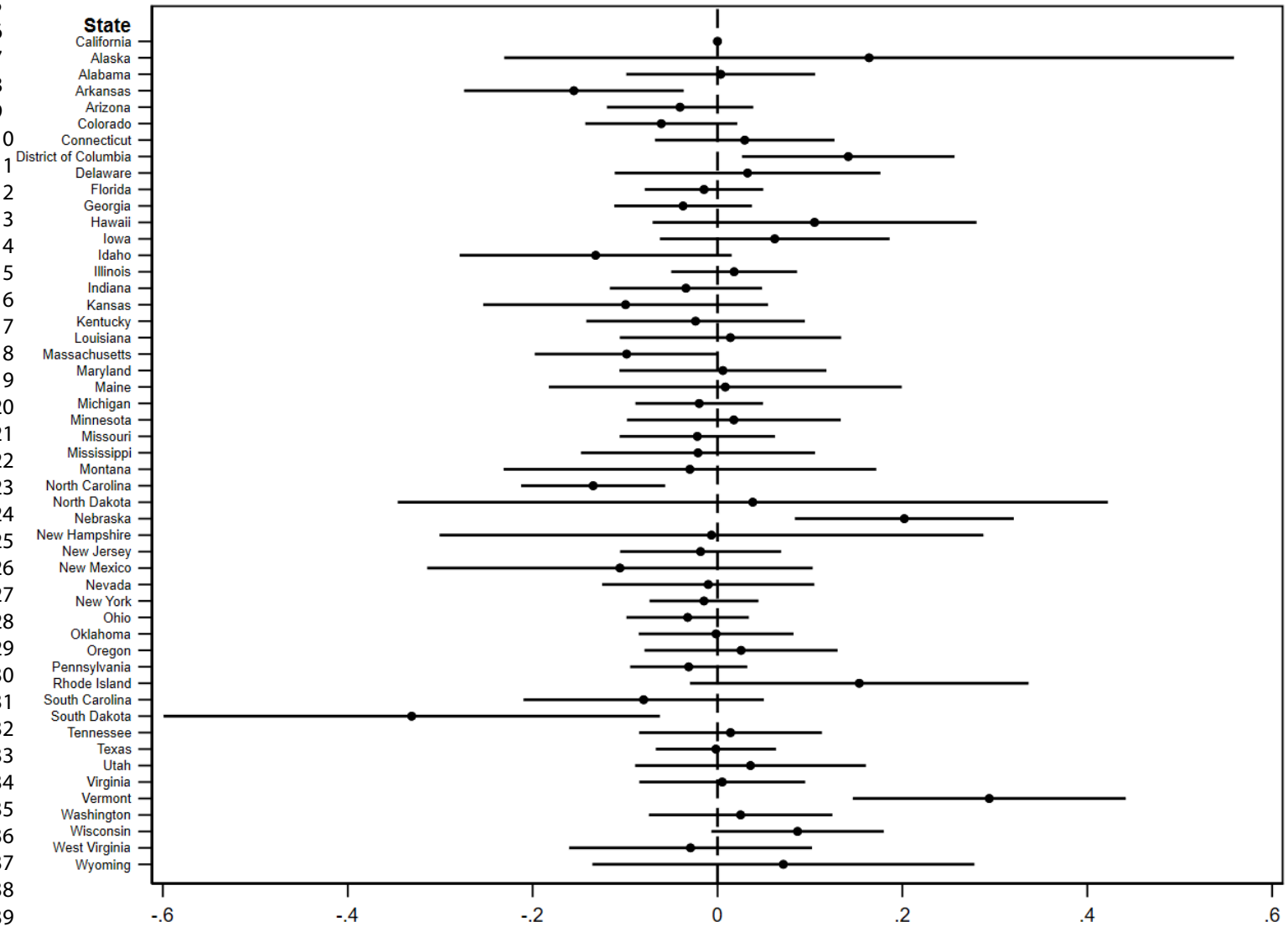
Note: N = 10,417 (September 2020 – November 2020). N = 7,814 (December 2020 – February 2021). N = 18,231 (September 2020 – February 2021). Green squares are the estimated correlations based on model II in Table A4 (September 2020 - November 2020). Blue circles are the estimated correlations based on the same model for September 2020 – November 2020. Red triangles are the estimated correlations based on the same model for December 2020 – February 2021. All models include control for country dummies. Horizontal lines are the associated 95 % confidence intervals.

Figure A10: Individual-level predictors in the US, controlling for region dummies



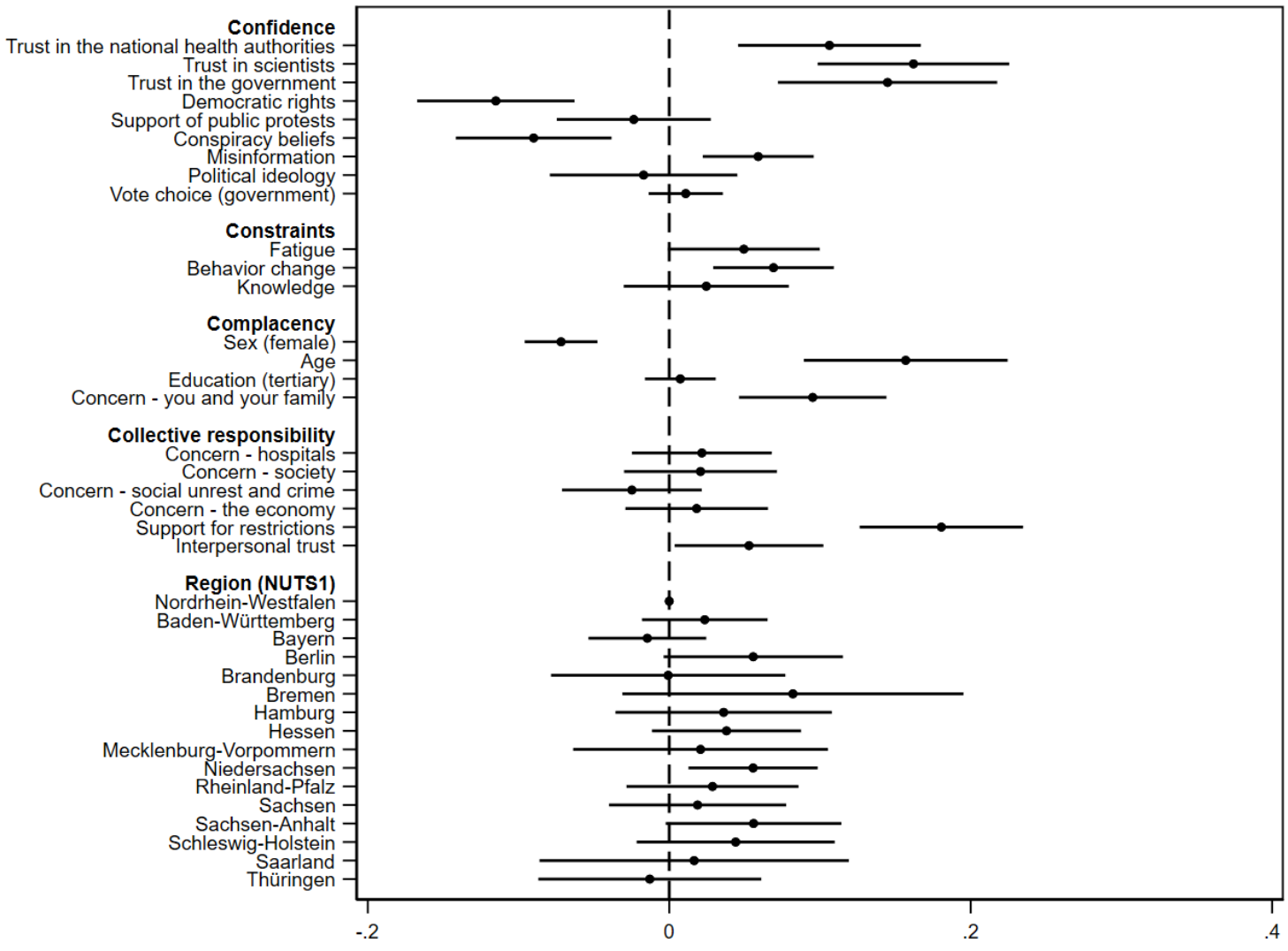
Note: N = 2,185. Circles are the estimated correlations. Horizontal lines are the associated 95 % confidence intervals.

Figure A11: Individual-level predictors in the US, controlling for state dummies



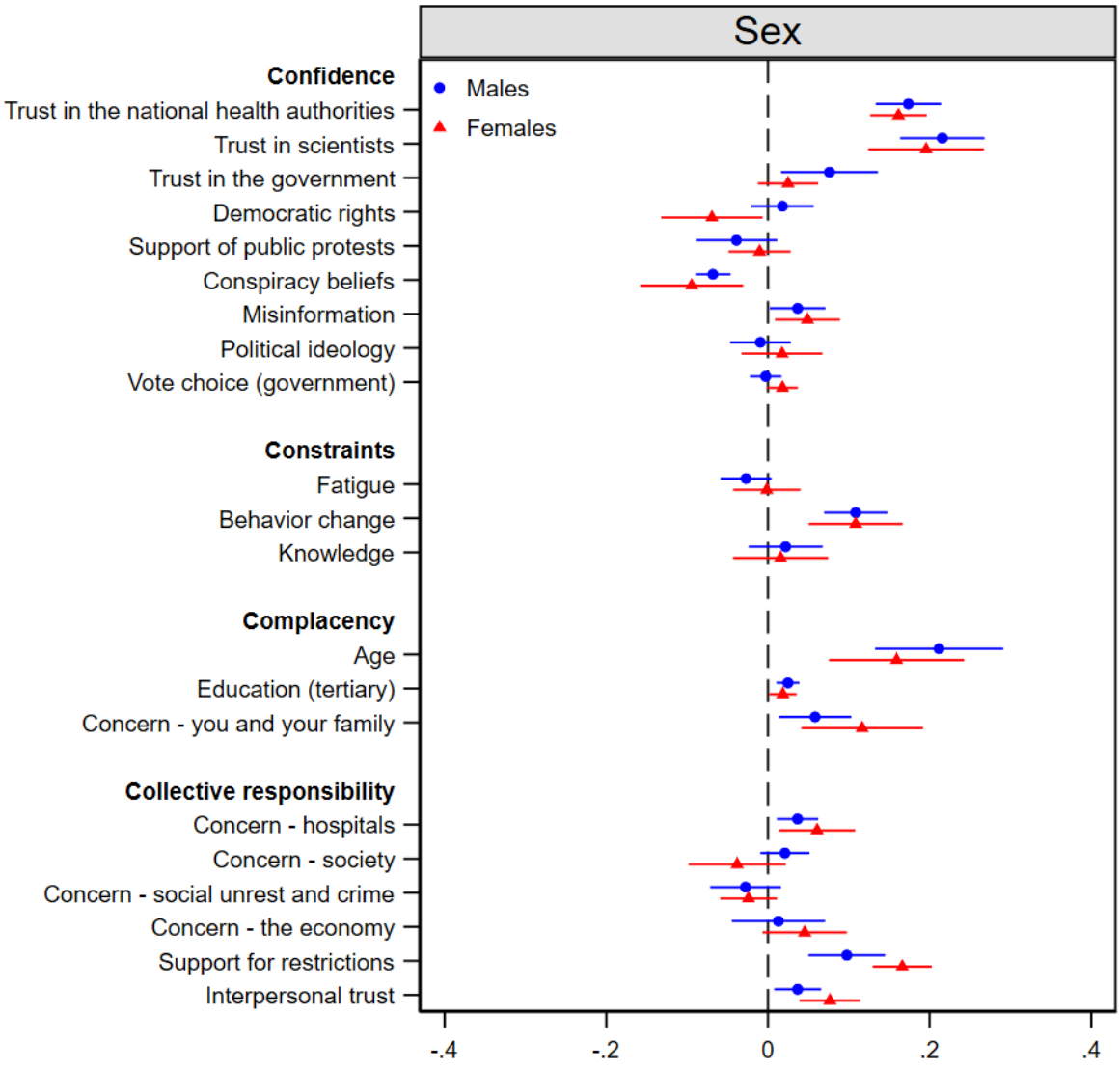
Note: N = 2,185. Circles are the estimated correlations. The model include all predictors from model II in table A4, controlling for state dummies instead of country level dummies. For simplicity, only the estimated correlations for the state dummies are illustrated here. Horizontal lines are the associated 95 % confidence intervals.

Figure A12: Individual-level predictors in Germany, controlling for state dummies



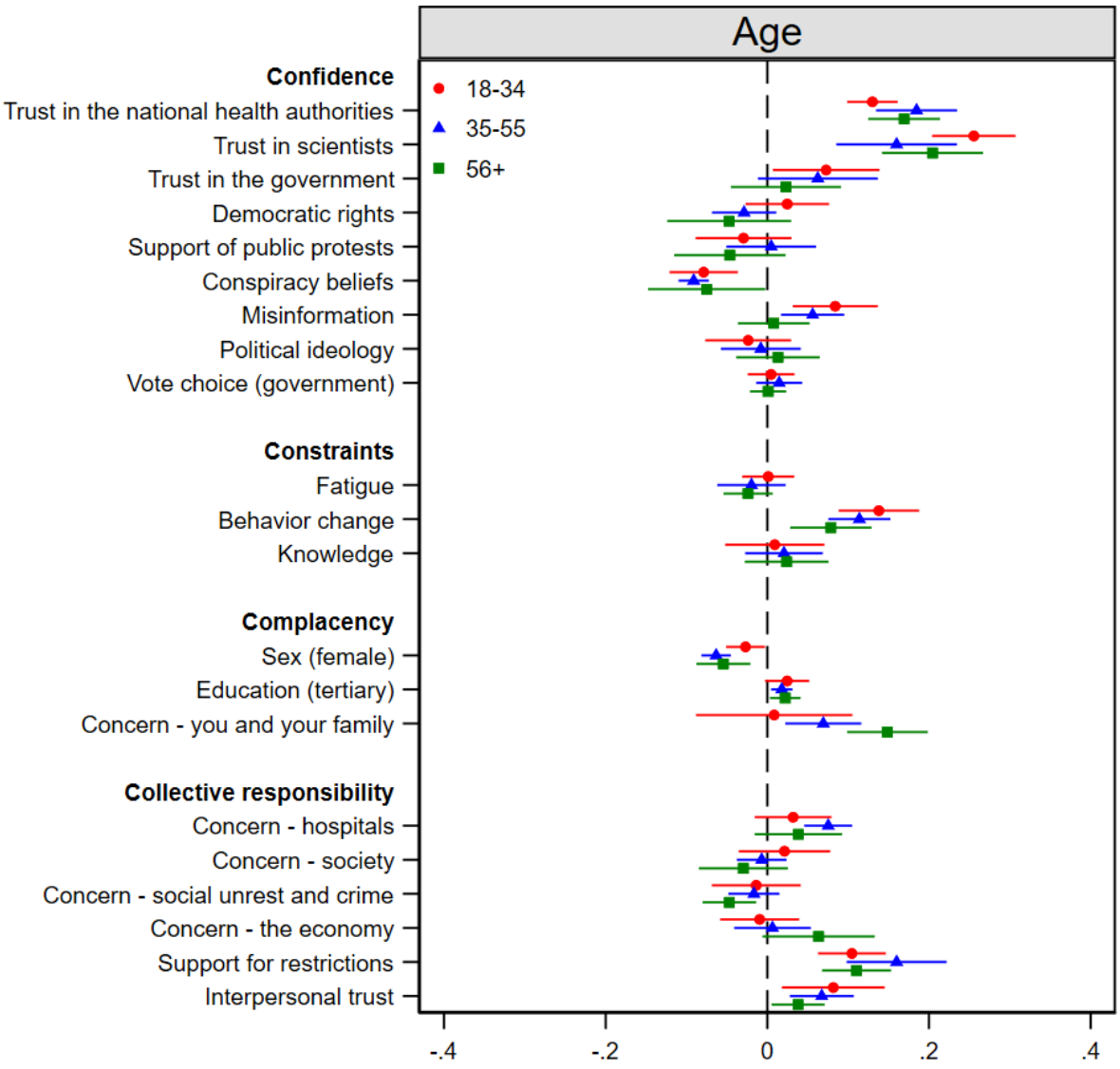
Note: N = 2,380. Circles are the estimated correlations. Horizontal lines are the associated 95 % confidence intervals.

Figure A13: Subgroup analysis – sex



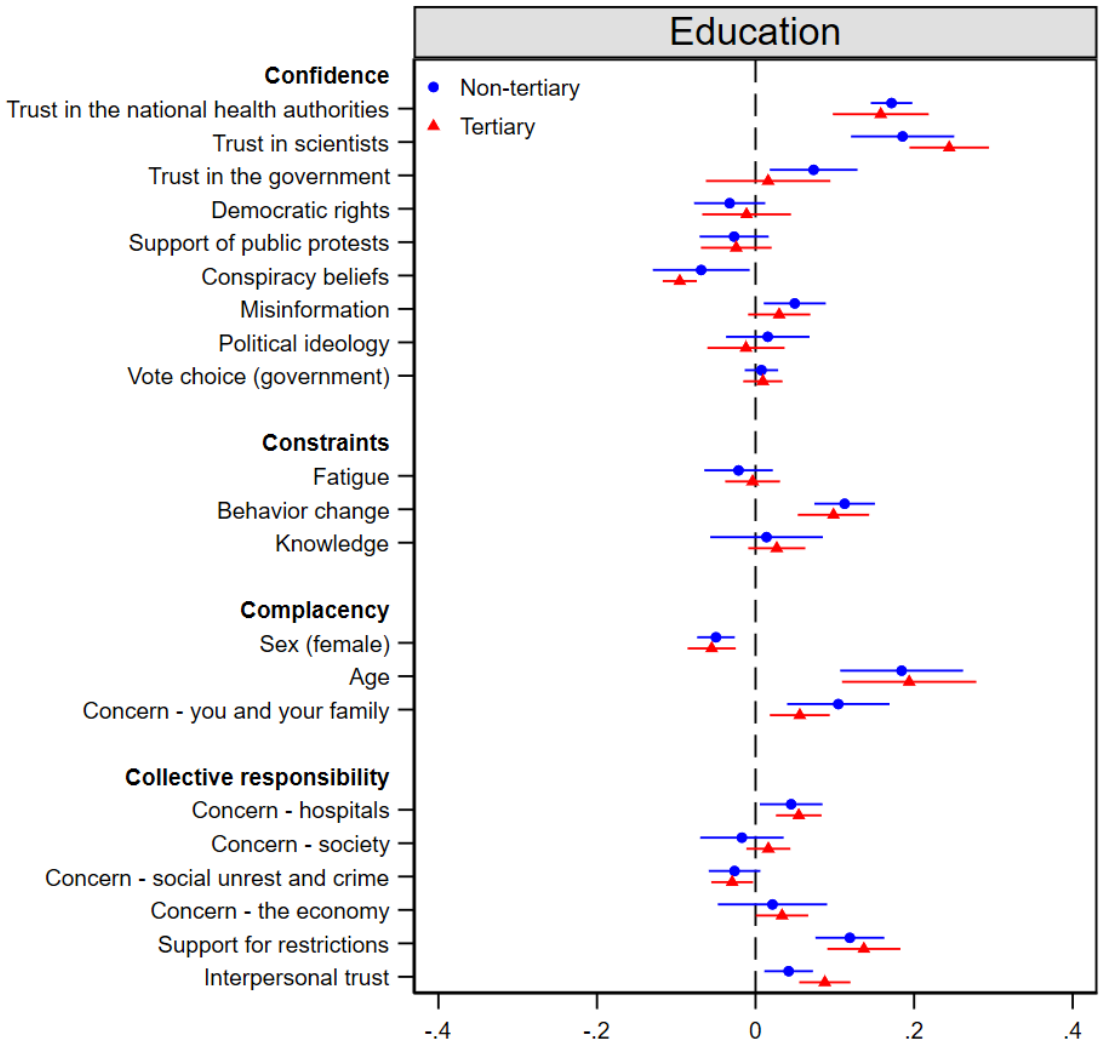
Note: N = 18,231. Blue circles and red triangles are the estimated correlations. Horizontal lines are the associated 95 % confidence intervals.

Figure A14: Subgroup analysis – age



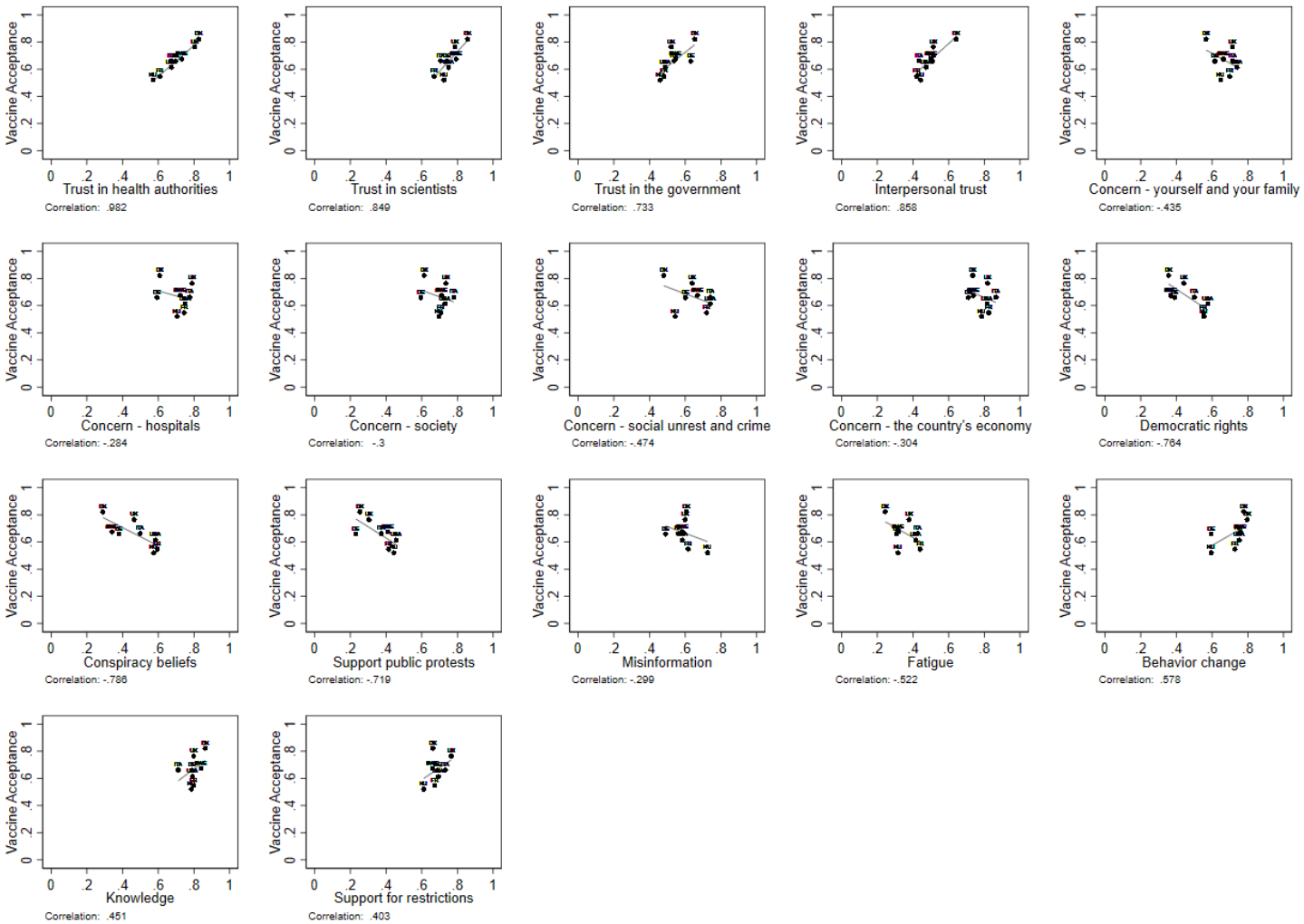
Note: N = 18,231. Red circles, blue triangles and green squares are the estimated correlations. Horizontal lines are the associated 95 % confidence intervals.

Figure A15: Subgroup analysis – education



Note: N = 18,231. Blue circles and red triangles are the estimated correlations. Horizontal lines are the associated 95 % confidence intervals.

Figure A16: Macro-level correlations of vaccine acceptance



Note: The figure plots country averages for vaccine acceptance and country averages for the range of non-background measures. Reported correlations are pearson's r.

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	0
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	1
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	7-8
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7-8
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	7-8
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8-12
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	8-12
Bias	9	Describe any efforts to address potential sources of bias	
Study size	10	Explain how the study size was arrived at	7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	11-12
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	12-13
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	12
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	12-13
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	2 + Table A1 in the OA
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Table A2 in the OA
		(b) Indicate number of participants with missing data for each variable of interest	
Outcome data	15*	Report numbers of outcome events or summary measures	11 + Figure 1
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	14-16 + Figure 2 + Table A4 in the OA
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	16 + OA
Discussion			
Key results	18	Summarise key results with reference to study objectives	16-17
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	18
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	
Generalisability	21	Discuss the generalisability (external validity) of the study results	18
Other information			16-19
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	2

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Public Acceptance of COVID-19 Vaccines: Cross-National Evidence on Levels and Individual-Level Predictors Using Observational Data

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May 12, 2021

Public Acceptance of COVID-19 Vaccines: Cross-National Evidence on Levels and Individual-Level Predictors Using Observational Data

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Abstract

Objectives

The management of the COVID-19 pandemic hinges on the approval of safe and effective vaccines but, equally importantly, on high vaccine acceptance among people. To facilitate vaccination acceptance via effective health communication, it is key to understand levels of vaccine skepticism and the demographic, psychological and political predictors. To this end, we examine the levels and predictors of acceptance of an approved COVID-19 vaccine.

Design, setting and participants

We examine the levels and predictors of acceptance of an approved COVID-19 vaccine in large online surveys from eight Western democracies that differ in terms of the severity of the pandemic and their response: Denmark, France, Germany, Hungary, Sweden, Italy, United Kingdom, and United States (total N = 18,231). Survey respondents were quota sampled to match the population margins on age, gender, and geographic location for each country. The study was conducted from September 2020 to February 2021, allowing us to assess changes in acceptance and predictors as COVID-19 vaccine programs were rolled out.

Outcome measure

The outcome of the study is self-reported acceptance of a COVID-19 vaccine approved and recommended by health authorities.

Results

The data reveal large variations in vaccine acceptance that ranges from 82 % in Denmark to 52 % in Hungary. Lack of vaccine acceptance is associated with lack of trust in authorities and scientists, conspiratorial thinking, and a lack of concern about COVID-19.

Conclusion

Most national levels of vaccine acceptance fall below estimates of the required threshold for herd immunity. The results emphasize the long-term importance of building trust in preparations for health emergencies such as the current pandemic. For health communication, the results emphasize the importance of focusing on personal consequences of infections and debunking of myths to guide communication strategies.

Article Summary

Strengths and limitations of this study

- Large samples that are reflective of the populations of eight different countries, allowing us to examine the generalizability of findings and the factors underlying cross-national differences.
- A broad-based assessment of potential correlates of vaccine acceptance, including both demographics, political, and COVID-specific factors.
- Analyses that includes observations both pre- and post-approval of COVID-19 vaccines.
- Observational data which limits causal traction.
- Self-reported vaccine acceptance can be subject to social desirability bias, and does not necessarily translate into actual vaccination rates.

Acknowledgements: We are grateful for research assistance from Magnus Storm Rasmussen.

Funding statement: This work was supported by The Carlsberg Foundation grant number CF20-0044 to Michael Bang Petersen. The funders had no role in the conduct of this research.

Ethical statement: The study complies with Aarhus University's Code of Conduct as well as the Committee Act of the Danish National Committee of Health Research Ethics, which states that "Surveys using questionnaires and interviews that do not involve human biological material (section 14(2) of the Committee Act)" are exempted from approval (https://en.nvk.dk/how-to-notify/what-to-notify)

Competing interests: None.

Author Contributions: MFL, FJ, AB and MBP designed the study and collected data. MFL and FJ analyzed data. MFL, FJ, AB and MBP wrote the paper.

Data sharing statement: Upon publication data will be publicly available at a repository at Open Science Framework.

Word count: 5,049.

Background

A vaccine against COVID-19 is a "vital tool" in the management of the current pandemic.[1] Accordingly, extraordinary resources have been invested into vaccine development with unprecedented speed. Yet, even as approved vaccines become available, societies across the world still face another challenge: Vaccine skepticism.

As of late 2020, researchers estimated that up to 82 percent of a country's population may need to be vaccinated in order to reach herd immunity against SARS-CoV-2,[2-3] and the emergence of new virus variants implies that individuals may need to get vaccinated repeatedly. However, general vaccine hesitancy has been on the rise in recent years in many countries.[4-5] This has been the case for many non-COVID-19 vaccine programs, and is likely to pose a challenge for COVID-19 vaccines.[6-7] Consistent with this, initial cross-national survey evidence suggests that substantially fewer people worldwide are willing to get vaccinated than would be necessary; and that some countries – e.g. Russia, Poland and France – face strikingly high levels of skepticism.[8] Thus, a key challenge for pandemic management is for health authorities across the world to encourage people to accept approved COVID-19 vaccines through careful approval procedures and effective health communication. This latter challenge emphasizes the importance of understanding why people are hesitant about taking vaccines. Such knowledge is crucial for guiding communication in a way that increase vaccine acceptance and for understanding how to prepare for future health emergencies.

In this manuscript, we *first* present descriptive analyses of the acceptance of a COVID-19 vaccine approved and recommended by health authorities across eight Western democracies. *Second*, we investigate individual-level predictors of vaccine acceptance. *Third*, we also explore macro-level correlations of vaccine acceptance. The study was conducted from the fall of 2020 to the winter of 2021. This data collection thus allows us to track levels and predictors of vaccine acceptance as vaccines were approved using large-scale cross-national surveys including a broad set of potential predictors, including political predictors, which are less-often explored in traditional health research. Given the scale and broad impact of a pandemic crisis, however, such broader predictors may be particularly relevant to explore.

Potential predictors: Who are expected to accept a COVID-19 vaccine?

To organize our expectations about the individual-level predictors of vaccine acceptance during the COVID-19 pandemic, we draw on one of the most comprehensive frameworks for understanding the antecedents of vaccine acceptance; the 5C model from Betsch et al. (2018).[9] According to the 5C model, five psychological antecedents drive vaccine acceptance: *confidence, constraints, complacency, calculation and collective responsibility*. While we consider multiple predictors that are often not considered within this model, we strengthen the model's coverage by theorizing the link between the components of the model and the novel predictors that may be important for vaccine acceptance during the COVID-19 pandemic.

Confidence is defined as trust in (i) the effectiveness and safety of vaccines, (ii) the system that delivers them, and (iii) the motivation of policy-makers who decide on the need of vaccines.[9-10] Here, we consider two categories of predictors that reflect the underlying dimensions of confidence. First, we broadly tap into the second dimension of the definition by focusing on trust in a range of actors. Second, we investigate a range of disease-specific attitudes that broadly reflect the third dimension of the definition.

Empirically, trust is a crucial predictor of vaccine acceptance. Guay et al. (2019), for example, found that distrust in public health authorities is associated with general vaccine hesitancy.[11] Similarly, people who trust official authorities, were more likely to accept the HPV vaccine.[12] Initial work on COVID-19 vaccines also demonstrates that those who have higher trust in scientists are more willing to get vaccinated.[13]

Furthermore, the literature on vaccine hesitancy has found that hesitancy is integrated into a broader set of political attitudes and perceptions. Political ideology has been found to be related to vaccine hesitancy as conservative individuals are less likely to trust authorities.[14] Furthermore, it is a standard finding in political science that individuals are less likely to accept decisions from other political parties than they one they identify with or vote for.[15] Thus, it is plausible that people who have voted for the government party/candidate are more likely to accept a vaccine, since the vaccine program is a part of the governments' response to the pandemic. In addition to these standard political attitudes, more extreme attitudes may also influence confidence in vaccines. Most prominently, people prone to conspiracy thinking are more likely to be hesitant about vaccines.[16-17] In the current context, higher levels of

coronavirus conspiracy thinking have also been found to be associated with lower acceptance of future vaccines against COVID-19.[18, 19, although see 20] Consequently, it can be expected that the COVID-19 pandemic may elicit anti-systemic sentiments. We examine three levels of anti-systemic sentiments and how they relate to vaccine acceptance, including (1) concern for democratic rights, (2) support of public protests against government policies, and (3) beliefs in specific conspiracy theories related to COVID-19. Finally, we also examine the role of awareness of misinformation. From the literature, we know that susceptibility to misinformation negatively affects people's acceptance of a vaccine against COVID-19.[21] However, studies have also shown that pre-bunking can help cultivate "mental antibodies" against misinformation.[22-23] Thus, it is likely that awareness of misinformation is positively associated with vaccine acceptance.

Constraints refer to the structural and psychological barriers, impeding the implementation of vaccination intentions into behavior.[9] We consider the feeling of "pandemic fatigue" as such a barrier and thus a potential correlate of vaccine acceptance. While the WHO has been warning about fatigue among populations in the fall of 2020,[24-25] it is plausible that people who feel fatigued are willing to do what it takes to end the pandemic including being vaccinated. However, perhaps paradoxically, fatigue could also generate an unwillingness or incapability to comply with further requirements including vaccinations. Furthermore, we include the sense of having sufficient knowledge about behavioral recommendations as another psychological barrier. A sense of self-efficacy about proper behavior was one of the best predictors of compliance with physical distancing policies during the first wave of the pandemic.[26] Furthermore, perceived insufficient knowledge is significantly associated with general vaccine hesitancy.[11] Finally, we assess remaining psychological constraints by assessing to what extent people report being able to change their behavior in accordance with the recommendations from the health authorities during the pandemic. This general measure of behavior change should serve as a proxy for the range of constraints that may serve as a barrier for action over and beyond the directly assessed factors.

Complacency "exists where perceived risks of vaccine-preventable diseases are low and vaccination is not deemed a necessary preventive action".[9-10] Here we consider two types of predictors, including demographic factors and corona-specific risk-perceptions.

First, a set of demographic predictors are expected to be associated with complacency. Thus, prior studies have found that males are more likely than females to accept a potential COVID-

19 vaccine [27-29], potentially due to sex-based differences in COVID-19 mortality.[27] Likewise older people are expected to be more willing to take a vaccination due to higher risks of severe infections. This is supported by Lazarus et al. (2020)[8] and Hacquin et al. (2020)[29], while neither Dror et al. (2020)[27] nor Wong et al. (2020)[28] found any age differences in vaccine acceptance. As a final demographic variable, we also consider education, even though this variable may influence vaccine acceptance through other dimensions than complacency (e.g., confidence). The findings of prior studies on vaccine hesitancy are mixed with regards to education, indicating that that the association between education and vaccine hesitancy is context specific.[30] To illustrate, whereas Guay et al. (2019) find that lower education is associated with general vaccine hesitancy in Canada,[11] Wagner et al. (2019) find that educational level is *not* associated with general vaccine hesitancy across five low-middle and middle-income countries.[30] Similarly, Bertoncello et al. (2020) find that while low parent education is significantly associated with general vaccine hesitancy, it is *not* associated with hesitancy in the context of child vaccine programs in Italy.[31] In the context of COVID-19, studies have found that higher education is associated with higher levels of vaccine acceptance.[8, 29]

Second, we also investigate the role of personal risk-perceptions. Several studies have found that self-perceived risks of COVID-19 positively predicts acceptance of potential COVID-19 vaccines.[19, 27, 29] Likewise, Wong et al. (2020) argued that perceived susceptibility to infection predicted the intention to take a future COVID-19 vaccine.[28] Thus, we expect that personal risk-perception predicts vaccine acceptance.

Collective responsibility is defined as the willingness to protect others by one's own vaccination by means of herd immunity.[9, 32] We consider three groups of predictors to be relevant for this category of vaccine antecedents: (1) prosocial concern (i.e., concern for others), (2) support for pandemic restrictions, and (3) interpersonal trust.

Focusing *first* on prosocial concerns, we measure a range of concerns over the disease's impact on society, including hospitals' ability to help the sick, society's ability to help the disadvantaged, social unrest and crime, and the country's economy. These concerns clearly tap into the collective responsibility and can be expected to positively predict vaccine acceptance given that vaccine uptake can be viewed as a form of other directed behavior that protects individuals beyond the self.

Second, we examine the association between compliance during the COVID-19 pandemic and vaccine acceptance. Protective behavior thus might be viewed as a collective good, implying that compliance with health advice might reflect the willingness to protect others rather than being individually rational to protect oneself.[33] Here, we specifically investigate support for non-pharmaceutical interventions, i.e., government restrictions to stop infection spread as a direct measure of the acceptance of collective responsibility.

Third, interpersonal trust may be a key predictor of the willingness to contribute to collective action during the COVID-19 pandemic.[33] Vaccinations is a form of collective action, where herd immunity is produced via the collective participation in vaccination programs,[34] and people may be more likely to participate if they trust others to do the same.

Table 1 in the measurement section, shows the specific operationalization of each of these predictors and summarizes how these predictors are related to the 5C model. As is evident, we do not include measures that reflect the *calculation* component of the 5C model. From a communication perspective, however, this component is less important as it refers not to the content of the individual's considerations but to more stable individual differences in decision-making style (i.e., extensive cost-benefit analyses of pros and cons of vaccination and infection).[9]

Methods

Patient and public involvement. Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Data. We fielded quota-sampled surveys in eight countries from September 13, 2020 until February 16, 2021: Denmark, Sweden, the United Kingdom, the United States of America, Italy, France, Germany and Hungary (please see Table A1 in the Online Appendix (OA) for an overview of the data collection). These countries were chosen to represent a diversity of national responses to the COVID-19 pandemic as well as a diversity in the severity of the local epidemic. The period consists of eight data rounds in Denmark and seven data rounds in the remaining countries with approximately 500 respondents per data round. In each of the eight countries, the survey company Epinion sampled adult respondents using online panels. Among the panelists invited to take our survey, the response rate across the countries in our sample

was between 18 % (Hungary) and 64 % (the United States). The survey was conducted in accordance with the guidelines of the Danish National Committee of Health Research Ethics for survey research that do not involve human biological material. Survey respondents were quota sampled to match the population margins on age, gender, and geographic location for each of the eight countries. We address imbalances by post-stratifying our sample data to match the demographic margins from the population. All statistical analyses presented in the manuscript employ these post-stratification weights.

Measures

All measures are self-reported from participant questionnaires. The key measures are vaccine acceptance, trust in relevant authorities and groups, disease-specific risk-perceptions, disease-specific attitudes, and propensities to engage in protective behavior. Table 1 provides an overview of question wordings and scales for these measures.

Table 1: Main measures in the study

	Questions	**Values**
Vaccine acceptance	If the health authorities advise people like me to get an approved vaccine against the coronavirus, I will follow their advice.	1. Completely disagree 2. Somewhat disagree 3. Neither agree nor disagree 4. Somewhat agree 5. Completely agree
Confidence	*Trust in health authorities and scientists* How much trust do you have in the following institutions regarding the coronavirus crisis? 1) The national health authorities 2) Scientists	1. Not at all 2. To a lesser degree 3. To a certain degree 4. To a high degree
	Trust in the government Give your assessment on a scale from 0 to 10, where 0 indicates that you have no confidence in the government at all, and 10 indicates that you have full confidence in the government.	0. No confidence at al 1. 2. 3. 4. 5. 6.

		7. 8. 9. 10. Full confidence
	Attitudes To what extent do you agree with the following statements? (1) I'm concerned about my democratic rights in the current circumstances (2) I support the public protests against the government's policies during the COVID-19 pandemic (3) I believe the government is hiding important information from the public about the coronavirus and its cures (4) I have heard or read information about the coronavirus and its cures, which I believe was probably false	1. Completely disagree 2. Somewhat disagree 3. Neither agree nor disagree 4. Somewhat agree 5. Completely agree
	Vote choice What party/who did you vote for in the last general election/presidential election? [date for last election]	[country-specific party/candidate categories]
	Ideology In political matters, people talk of 'the left' and 'the right'. How would you place your views on this scale, generally speaking?	1. The left 2. 3. 4. 5. 6. 7. 8. 9. 10. The right
Constraints	*Fatigue* To what extent do you agree with the following statements? I do not think I can keep up with the restrictions against the coronavirus for much longer.	1. Completely disagree 2. Somewhat disagree 3. Neither agree nor disagree 4. Somewhat agree 5. Completely agree
	Behavior change To what degree do you feel that the current situation with the coronavirus has made you change your behavior to avoid spreading infection?	1. Not at all 2. To a lesser degree 3. To a certain degree 4. To a high degree
	Knowledge	1. Not at all 2. To a lesser degree 3. To a certain degree 4. To a high degree

	To what degree do you feel that you know enough about what you as a citizen should do in relation to the coronavirus?	
Complacency[1]	*Sex* Are you?	1. Male 2. Female
	Age What is your age?	[open textbox]
	Education What is your highest level of completed education?	[country-specific education categories]
	Personal risk-perceptions To what degree are you concerned about the consequences of the corona-virus for you and your family?	1. Not at all 2. To a lesser degree 3. To a certain degree 4. To a high degree
Collective responsibility	*Prosocial concerns* To what degree are you concerned about the consequences of the corona-virus… (1) … for hospitals' ability to help the sick? (2) … for society's ability to help the disadvantaged? (3) … on social unrest and crime? (4) … on the country's economy?".	1. Not at all 2. To a lesser degree 3. To a certain degree 4. To a high degree
	Support for restrictions As you may know, many countries have implemented various measures to stop the spread of the COVID-19 epidemic. We are interested in whether you support or oppose the following measures in your country: (1) Closing of schools and universities (2) Closing (or work from home) for all-but-essential workplaces (e.g. grocery shops, doctors) (3) Cancelling public events (4) Cancelling private gatherings with over 100 people (5) Closing public transportation	1. Oppose 2. Support

[1] See text for discussion of the relationship between demographic variables and complacency (p. 5-6).

	(6) Ordering people to shelter-in-place (not leaving house with minimal exceptions) (7) Restricting internal movement between cities/regions (8) Ordering people to wear face masks in public places (9) Banning arrivals for foreign travelers from some regions.	
	Interpersonal trust Do you think that most people by and large are to be trusted, or that you cannot be too careful when it comes to other people?	0. You cannot be too careful 1. 2. 3. 4. 5. 6. 7. 8. 9. 10. Most people are to be trusted

Notes: Mean and standard deviation of all measures is available in table A2 in the OA.

Vaccine acceptance

Our outcome, vaccine acceptance, is measured using the following question: "If the health authorities advise people like me to get an approved vaccine against the coronavirus, I will follow their advice". Thus, our measure is framed as an approved vaccine that is recommended by the national health authorities. This choice reflects that (1) we focus on COVID-19 vaccines specifically, (2) during a global health crisis, where health authorities are emergency approving and very actively encouraging people to take up new vaccines. Some of these important factors are overlooked by previous validated vaccine acceptance measures developed pre-pandemic for measuring attitudes towards vaccines in general. Framing the question in the context of the national health authorities may, however, yield different results than if a standardised and validated measure of vaccine acceptance was used. Furthermore, this choice makes it difficult to compare our results with other studies of vaccine acceptance.[9] Although Betsch et al. (2018) recommend to use a general scale, they also acknowledge that this might not be useful when the focus of a study is on a specific vaccine.[9]

Our outcome, vaccine acceptance, is a continuous variable rescaled to range from 0-1, with higher values indicating higher levels of acceptance of a future COVID-19 vaccine.

Predictors of vaccine acceptance

All measures of trust, concern and disease-specific attitudes are treated as continuous variables and rescaled from 0-1, with higher values indicating higher levels of trust, concern and agreement with the disease-specific statements. For our compliance measures, behavior change and knowledge are treated as continuous variables and rescaled to range from 0-1, with higher values indicating higher levels of behavior change and knowledge. Furthermore, we create an index of support for restrictions by adding together the nine measures of support for restrictions. The index is scaled from 0-1, with higher values indicating higher levels of support for restrictions. "Do not know" answers are classified as missing and are not included in the analysis. Sex is an indicator variable (0 for males; 1 for females). Age is a continuous variable rescaled from 0-1 with 0 being the minimum age in the sample (18 years) and 1 being the maximum age (99 years). Education is an indicator variable based on the internationally comparable ISCED-scale (0 for non-tertiary education; 1 for tertiary education). Vote choice is an indicator variable (0 for opposition; 1 for government) (see table A3 in the OA for the coding of this variable). Finally, political ideology is a continuous variable rescaled to range from 0 to 1, with 1 indicating the ideological standpoint to the utmost right.

To ease the interpretation of the results, both the outcome and all predictors are scaled from 0-1 in the analyses below. Table A2 in the appendix reports the descriptive statistics for all the above correlates in our overall sample. Moreover, Figure A1 in the appendix shows an overview of all bivariate correlations.

Statistical analyses

Since our dependent variable, vaccine acceptance, is continuous, we use OLS regression models to investigate the individual-level predictors of vaccine acceptance. In the results section we present two models: (I) a model with all the bivariate correlations of vaccine acceptance, (II) a full model that includes all predictors described above. Model II includes country dummies to control for country specific effects. Thus, our aim is to identify individual-level predictors of acceptance of a COVID-19 vaccine. To account for the fact that individuals are nested within countries, we cluster the standard errors at the country level.

In the OA we conduct a range of sensitivity analyses that probe the robustness of our benchmark results. First, we replicate the main analyses while treating the 4-point scale

measures of trust, concern, behavior change and knowledge as categorical variables instead of continuous (see Figure A2-A5 in the OA). Second, we similarly replicate the analyses while using a dichotomous - rather than the continuous - coding of the outcome[2] (see Figure A6 in the OA). Third, the present results reflect the analysis period between September 13, 2020 and February 16, 2021. Thus, we include data both pre- and post-approval of the COVID-19 vaccines. In the OA, we compare the results before and after COVID-19 vaccines were approved (see Figure A7 in the OA). Fourth, in some contexts - most notably the countries with federal states (the US and Germany) in our sample - much of the COVID-19 response is done on a regional level. To account for state-specific heterogeneity, we analyze the individual-level predictors separately in Germany and the US, while controlling for state rather than country level dummies (see Figure A8-A10 in the OA). The results are essentially similar to those presented in the main text.

Results

Figure 1 shows the development in vaccine acceptance, by country. For the descriptive analyses below, we refer to the percentage who accept the vaccine (i.e. share of respondents who answered "Somewhat agree" or "Completely agree" to whether they will follow the advice of the health authorities and get an approved vaccine). This percentage refers to the level of vaccine acceptance for the full analysis period, i.e. September 2020 - February 2021.

[Figure 1 about here]

Across the eight countries, we observe large differences in the level of vaccine acceptance. Specifically, we observe the highest level of vaccine acceptance in Denmark (82 %). Furthermore, we observe a high level of vaccine acceptance in the United Kingdom (76 %). However, we observe only moderate levels of vaccine acceptance in Sweden (67 %), Germany (66 %), Italy (66 %), and the United States (61 %). The lowest levels of vaccine acceptance is observed in France (55 %) and Hungary (52 %). However, it is worth noticing that in most of

[2] For the dichotomous outcome measure, respondents who answered "Somewhat agree" or "Completely agree" are coded as 1, indicating vaccine acceptance.

the countries, we observe increasing levels of vaccine acceptance over the course of the pandemic as COVID-19 vaccines are being approved and rolled out.

The results indicate that vaccine skepticism is present in most of the countries in our sample. These results underscore two important points. First, the presence of vaccine skepticism demonstrates the importance of understanding the individual-level variation of vaccine acceptance in order to understand the targets of health communication. Second, the large variation across countries emphasizes the need of a more thorough understanding of the importance of national context. Therefore, we also move beyond the individual-level focus to explore macro-level correlations of vaccine acceptance.

On this basis, we first turn towards understanding the individual-level predictors of acceptance of a COVID-19 vaccine. Figure 2 presents the results of the analyses (see Table A4 in the OA). In the discussions of results below, we specifically focus on the estimated correlations from model II in table A4 (the full model). The size of the estimated coefficients reported below reflects the difference in vaccine acceptance when we compare individuals at the minimum and maximum values, respectively, for each of the correlates.

[Figure 2 about here]

Examining the *confidence* predictors, we observe that trust in the health authorities and trust in scientists are the strongest predictors of vaccine acceptance. Respondents who have the highest level of trust in the national health authorities have 17 (95% CI 14-20) percentage points higher acceptance of a COVID-19 vaccine compared to those with the least trust. The same pattern is observed for trust in scientists. Respondents with the highest level of trust have 21 (95% CI 16-26) percentage points higher acceptance of an approved COVID-19 vaccine compared to those with the lowest trust level. Furthermore, trust in the government is also significantly positively predicting vaccine acceptance. Respondents high in government trust have 5 (95% CI 0-10) percentage points higher acceptance of an approved COVID-19 vaccine compared to those with the lowest level of trust. Focusing on the attitudinal aspect of *confidence* predictors, we observe that conspiracy beliefs significantly negatively predict vaccine acceptance, while awareness of misinformation significantly positively predicts vaccine acceptance. Specifically, respondents who score highest in thinking that the government is hiding information about the

coronavirus and its cures (conspiracy beliefs), have 9 (95% CI 5-12) percentage points higher acceptance of an approved COVID-19 vaccine compared with those who do not subscribe to conspiracies. Respondents who think that they have been exposed to misinformation have 4 (95% CI 1-7) percentage points higher acceptance of an approved COVID-19 vaccine. Both concern about democratic rights and support for protests are negatively, but not significantly, associated with vaccine acceptance. Finally, neither political ideology nor vote choice are significantly associated with vaccine acceptance.

Moving to the *constraints* predictors, we observe that behavior change is a significant positive predictor of vaccine acceptance. Specifically, respondents who have changed their behavior the most to avoid spreading infection have 11 (95% CI 7-14) percentage points higher acceptance of an approved COVID-19 vaccine compared to respondents who have changed their behavior the least. Neither fatigue nor knowledge are significant predictors of vaccine acceptance.

Focusing on the *complacency* predictors, we observe that being male, older, and having tertiary education is associated with higher vaccine acceptance. Specifically, females have 5 (95% CI 3-7) percentage points lower acceptance of an approved vaccine compared to males. Age positively predicts vaccine acceptance: When comparing respondents at the minimum and maximum level of age in the sample (18-99 years), the difference is 19 (95% CI 12-26) percentage points. Furthermore, respondents with tertiary education have 2 (95% CI 1-3) percentage points higher acceptance of an approved COVID-19 vaccine compared to respondents with non-tertiary education. Finally, personal risk-perception is also a positive predictor of vaccine acceptance. The respondents who are the most concerned about the consequences of the corona crisis for themselves and their families have 9 (95% CI 3-14) percentage points higher acceptance of an approved COVID-19 vaccine compared to the least concerned.

Finally, looking at the *collective responsibility* predictors, the strongest predictors of vaccine acceptance is support for restrictions. Specifically, respondents who are most supportive of restrictions have 13 (95% CI 9-17) percentage points higher acceptance of an approved vaccine compared to respondents who are the least supportive of restrictions. Furthermore, interpersonal trust positively predicts vaccine acceptance. Respondents with the highest level of interpersonal trust have 6 (95% CI 3-9) percentage points higher acceptance of an approved COVID-19 vaccine compared to respondents with the lowest interpersonal trust level. Concern

for the capacity of hospitals is also a positive predictor of vaccine acceptance. Comparing those who are the most concerned for the capacity of hospitals to those who are the least concerned shows a 5 (95% CI 2-8) percentage points increase in vaccine acceptance. Additionally, concern for social unrest and crime negatively predicts vaccine acceptance. Comparing those who are the most concerned for social unrest and crime to those who are the least concerned shows a 3 (95% CI 1-5) percentage points decrease in vaccine acceptance. Finally, neither concern for the society's ability to help the disadvantaged nor concern for the country's economy are significantly associated with vaccine acceptance.

The relationship between the predictors and vaccine acceptance is essentially the same across the bivariate and the full model. However, ideology changes from being significant and negative in the bivariate model to insignificant and positive in the full model. Furthermore, concern for the society's ability to help the disadvantaged changes from being significant and positive in the bivariate model to insignificant and negative in the full model. Overall, the empirical patterns are relatively stable across countries, but we do observe some notable cross-country differences with respect to specific predictors (see Figure A11 and A12 in the OA). In Denmark, neither trust in scientists nor personal risk-perceptions are significant predictors of vaccine acceptance (see Figure A11 in the OA). Focusing on heterogeneity across individual-level demographic subgroups, we see that results are essentially homogenous across sex, age and educational level (see Figures A13-A15 in the OA). Even though the levels of vaccine acceptance has changed over the course of the pandemic, the results of the individual-level predictors of vaccine acceptance are essentially the same when results pre- and post-approval of COVID-19 vaccines are compared (see Figure A7 in the OA).

While trust in the national health authorities and scientists are the most prominent factors together with personal risk-perceptions when everything is assessed individually, the data also shows that vaccine skepticism during the pandemic is interwoven into a larger web of attitudes and behaviors related to anti-systemic sentiments. Hence, in addition to trust in health authorities, a lack of vaccine acceptance was also related to endorsement of conspiracy beliefs, support for other non-pharmaceutical interventions, and a lack of compliance with advice about changing behavior to avoid spreading infections.

As a final explorative analysis, we therefore assess whether the highlighted factors also help explain the cross-national variation in vaccine acceptance. To this end, we examine the correlations between vaccine acceptance at the national level and each of the different independent measures aggregated for each country. All of these correlations are available in Figure A16 in the OA. In Figure 3, we present the correlations for key variables highlighted above: Trust in health authorities, personal risk-perceptions, conspiracy beliefs and behavior change. While the analysis is highly limited by the fact that it only includes eight national cases, it is nonetheless strikingly informative. While differences in personal risk-perceptions are not strongly related to cross-national differences, country averages in the anti-systemic measures, especially (lack of) trust in health authorities, are exceptionally closely related to country averages in vaccine acceptance. Thus, trust in health authorities does not just explain differences in vaccine acceptance between individuals but also between countries.

[Figure 3 about here]

Discussion

In this paper, we investigated (1) the level of vaccine acceptance of an approved COVID-19 vaccine, (2) individual-level predictors of vaccine acceptance, and (3) macro-level correlations of vaccine acceptance. While levels of vaccine acceptance generally increased when COVID-19 vaccines were approved during the winter of 2020-2021, the results also demonstrate that for many of the countries in our sample, people are only moderately willing to receive a vaccine. This highlights the need for understanding the individual-level variation underlying vaccine skepticism and identifying potential targets for guiding health communication to increase vaccine acceptance.

The analyses of individual-level predictors demonstrate that the key drivers of COVID-19 vaccine acceptance are (1) trust in the national health authorities and scientists, and (2) personal health concerns. These results are consistent with findings of similar studies that emphasize that those who have more trust in experts and scientists are more willing to vaccinate.[13, 35] Likewise, several studies have also found personal risk-perception to be an important predictor of acceptance of a COVID-19 vaccine.[20, 27, 29, 36] Furthermore, Neumann-Böhme & Sabat (2020) find that the most frequently used reason for vaccination is to protect the respondents own and family members health.[37] Motta et al. (2020) also find that messages emphasizing

the personal risks at failing to vaccinate are effective in convincing people to plan to get vaccinated.[38] Thus, in the framework of the 5C Model from Betsch et al. (2020), skepticism towards a COVID-19 vaccine primarily results from *complacency* or a lack of *confidence*.[9] Using these insights is essential to guide health communication in a way that can potentially increase vaccine acceptance.[39] Specifically, our findings suggest that efforts should be focused on motivating the complacent, i.e. those who lacks concerns about the personal consequences of the pandemic. This can be done through informational interventions to explain disease risks and stress the social benefits of vaccination.[39] When it comes to individuals with a lack of confidence, they usually possess a considerable amount of incorrect knowledge that distorts risk perceptions and undermines the general trust in vaccination.[39] Consistent with this, the present findings also highlight conspiracy beliefs as a key predictor of vaccine hesitancy. Following Betsch et al. (2015), this implies that interventions aiming at debunking myths is the key to increase vaccine acceptance among those who lack confidence.[39] However, strategies aiming at those who lack confidence are scarce, thus, focusing on motivating the complacent may be more effective.[39] Altogether, these results suggest that the most important communication targets are the consequences of infections for the self and close others and debunking of myths.

In sum, these analyses point to the significant challenges involved in convincing vaccine skeptics. The web of anti-systemic attitudes and distrust that vaccine skepticism is interwoven in makes it difficult to craft efficient health communication, as the effectiveness of communication is fundamentally contingent on the preceding existence of trust in its source. This challenge might be further deepened during the COVID-19 pandemic as research suggests that the stress of the pandemic and the restrictions itself fuels anti-systemic beliefs.[40] The results thus, first, emphasize the general importance of building trust prior to the onset of crises and of investing significant resources into maintaining trust as a crisis unfolds.[41] Second, for most short-term oriented communication purposes, the results suggest that the best communication targets are the consequences of infections for the self and close others and debunking of myths.

The results should however be considered in the light of the following limitations. First, the results are based on observational data which limits causal traction. Second, we investigate self-reported vaccine acceptance, and thus, not actual vaccination behavior. Therefore, we cannot be sure that acceptance of the vaccine translates into actual vaccination rates, since self-

reported vaccine acceptance can be subject to social desirability bias. However, several studies have found a high level of consistency between self-reported vaccine acceptance and actual vaccination rates [42-44].

Conclusion

The results demonstrate that vaccine skepticism is present in most of the countries in our sample, even after vaccines have been approved. Consistent with similar studies, the analyses of the individual-level predictors show that the key individual drivers of acceptance of an approved COVID-19 vaccine are (1) trust in the national health authorities and scientists, and (2) personal health concerns. The results suggest that an important communication target is the consequences of infections for the self and close others. Furthermore, these results emphasize that anything that erodes trust in health authorities and scientists are problematic for vaccination efforts, and thus, underscore the key importance of health and political authorities to strive to uphold trust to the maximum extent during the pandemic. This is not just crucial for managing the pandemic here and now but also as a preparation for the next health emergency.

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Figure captions and legends

Figure 1: Development in vaccine acceptance for an approved COVID-19 vaccine

Note: N = 18,231. The figure illustrates the development in vaccine acceptance across countries. Vaccine acceptance is here defined as the proportion who answers "Somewhat agree" or "Completely agree" to the question: "If the health authorities advise people like me to get an approved vaccine against the coronavirus, I will follow their advice."

Figure 2: Individual-level correlations of vaccine acceptance

Note: N = 18,231. Black circles are the estimated correlations based on model I-II in Table A4 in the OA. Model II includes control for country dummies. Horizontal bars are the associated 95 % confidence interval.

Figure 3: Macro-level correlations of vaccine acceptance

Note: The figure plots country averages for vaccine acceptance and country averages for four measures: Trust in health authorities, egotropic concern related to COVID-19, endorsement of COVID-19 conspiracy beliefs and the degree of changed behavior to avoid spreading infections during the COVID-19 pandemic. Reported correlations are pearson's r.

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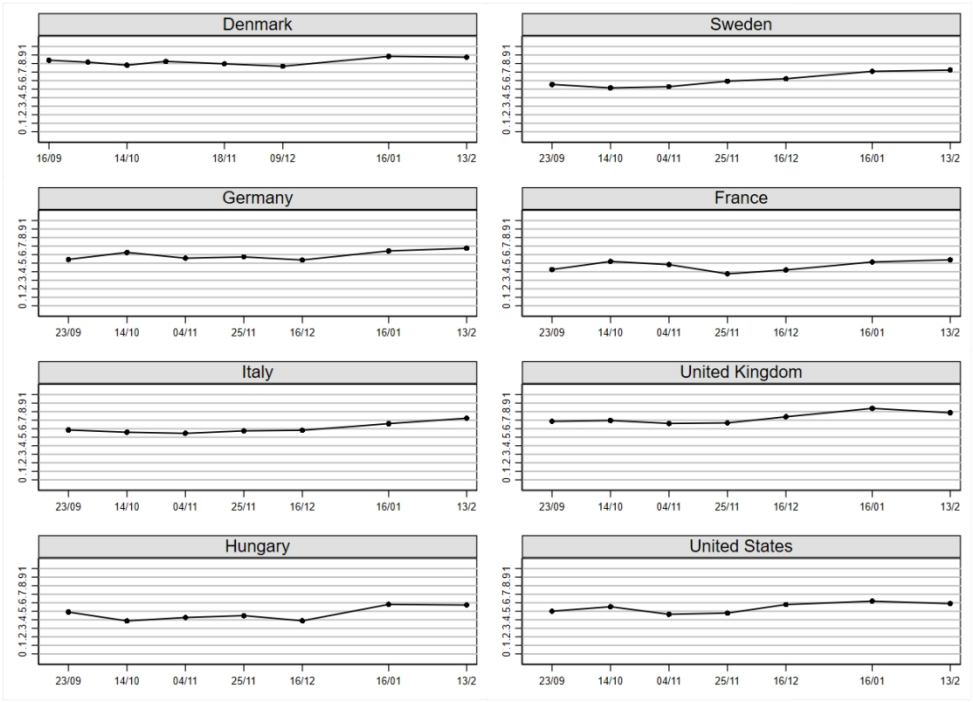

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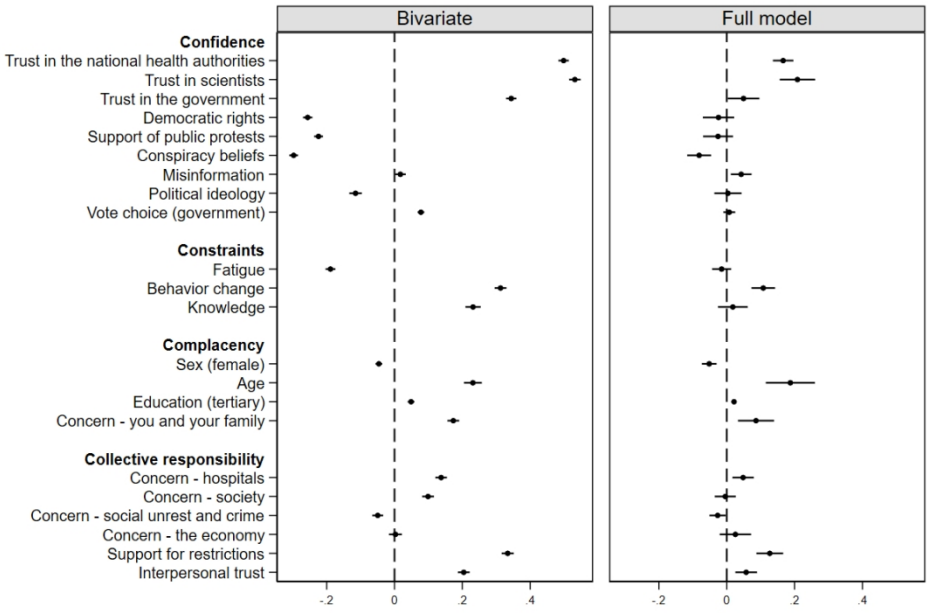

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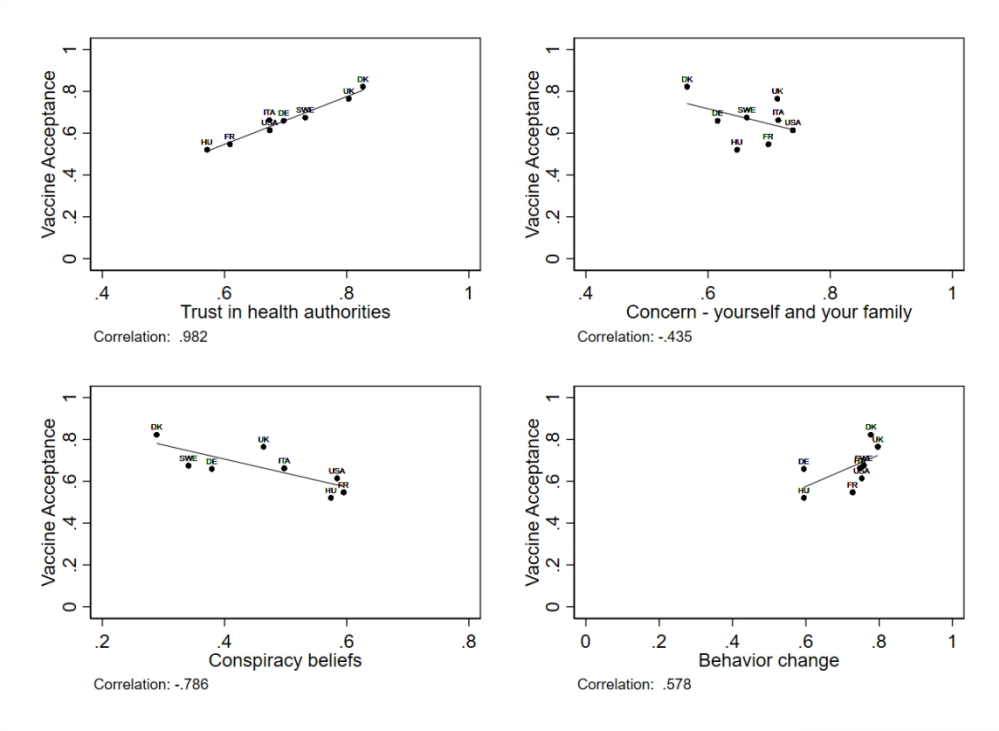

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Table A1: Overview of data collection

Country	Dates	Obs.
Denmark	September 13, 2020 – February 16, 2021	2,765
Sweden	September 20, 2020 – February 16, 2021	2,149
United Kingdom	September 20, 2020 – February 16, 2021	2,437
United States	September 20, 2020 – February 16, 2021	2,185
Italy	September 20, 2020 – February 16, 2021	2,411
France	September 20, 2020 – February 16, 2021	2,090
Germany	September 20, 2020 – February 16, 2021	2,380
Hungary	September 20, 2020 – February 16, 2021	1,814

Table A2: Descriptive statistics

	Mean	SD	Min	Max	N
Vaccine acceptance	0.66	0.34	0	1	18,231
Confidence					
Trust in national health authorities	0.70	0.29	0	1	18,231
Trust in scientists	0.76	0.26	0	1	18,231
Trust in the government	0.54	0.31	0	1	18,231
Concern about democratic rights	0.47	0.35	0	1	18,231
Support for protests	0.36	0.36	0	1	18,231
Conspiracy beliefs	0.46	0.36	0	1	18,231
Misinformation	0.60	0.31	0	1	18,231
Political ideology	0.50	0.26	0	1	18,231
Vote choice (government)	0.47	0.50	0	1	18,231
Constraints					
Fatigue	0.37	0.33	0	1	18,231
Behavior change	0.73	0.27	0	1	18,231
Knowledge	0.80	0.22	0	1	18,231
Complacency					
Sex (female)	0.46	0.50	0	1	18,231
Age	0.35	0.18	0	1	18,231
Education (tertiary)	0.50	0.50	0	1	18,231
Concern - you and your family	0.67	0.28	0	1	18,231
Collective responsibility					
Concern - hospitals	0.71	0.29	0	1	18,231
Concern - society	0.69	0.28	0	1	18,231
Concern - social unrest and crime	0.63	0.31	0	1	18,231
Concern - the country's economy	0.78	0.26	0	1	18,231
Support for restrictions	0.69	0.27	0	1	18,231
Interpersonal trust	0.50	0.28	0	1	18,231

Table A3: Coding of vote choice variable

Country	Government	Opposition
Denmark	Socialdemokratiet	Konservative
	Radikale	Nye Borgerlige
	Socialistisk Folkeparti	Klaus Riskjær Pedersen
	Enhedslisten	Liberal Alliance
		Kristendemokraterne
		Dansk Folkeparti
		Stram Kurs
		Venstre
		Alternativet
Sweden	Miljöpartiet	Kristendemokraterna
	Socialdemokraterna	Moderaterna
	Vänsterpartiet	Sverigedemokraterna
	Centerpartiet	
	Liberalerna	
United Kingdom	Conservative	Labour
		SNP
		Liberal Democrats
United States	Republicans	Democrats
Italy	Centre-Left	Centre-Right
	Five Star Movement	Free and Equal
France	Macron	Fillon
		Le Pen
		Dupont-Aignan
		Hamon
		Melenchon
Germany	CDU/SDU	AfD
	SPD	FDP
		Die Linke
		Grüne
Hungary	Fidesz-KDNP	Jobbik
		MSZP-MM
		LMP
		DK
		MM

Figure A1: Bivariate correlations

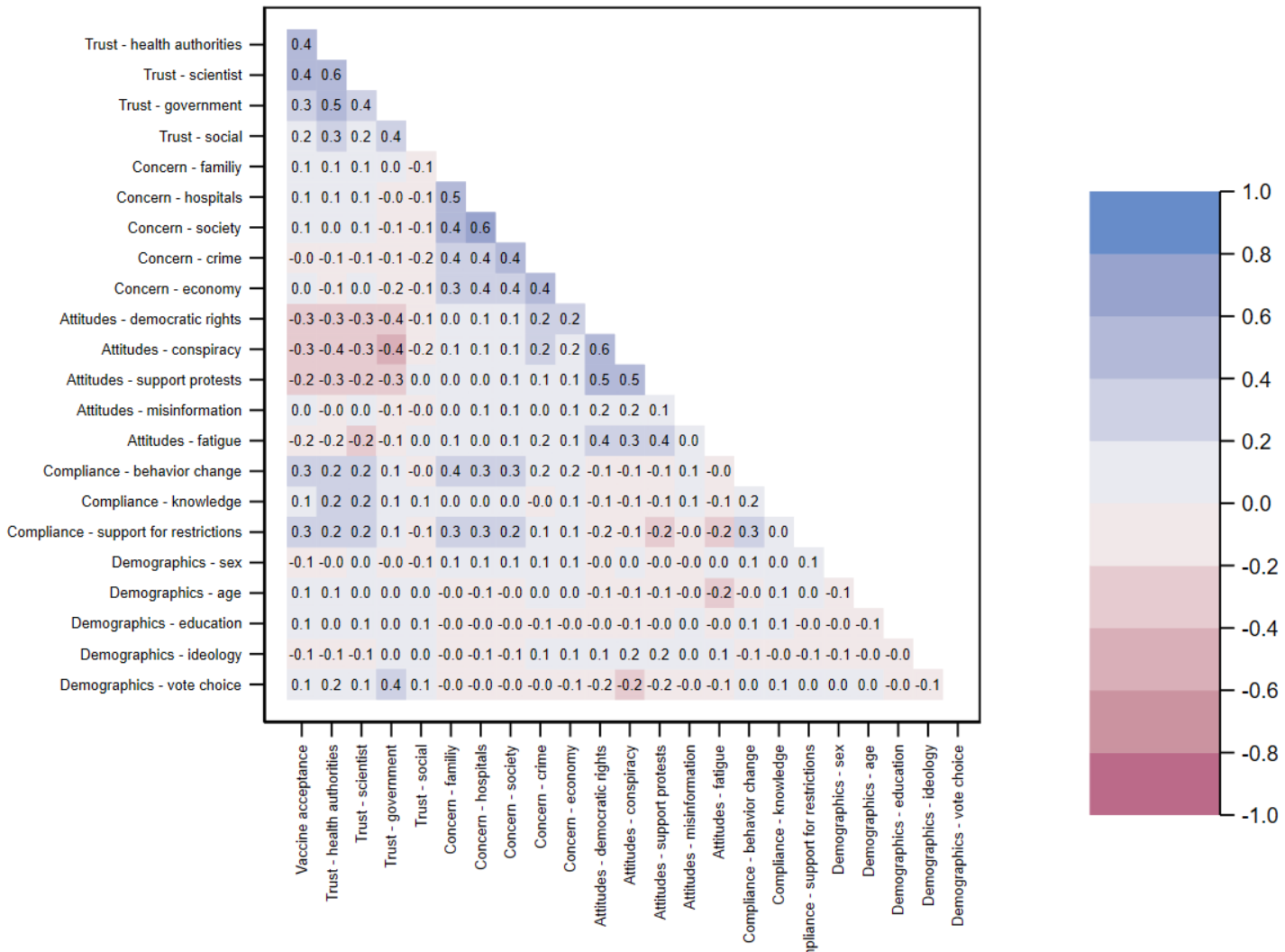
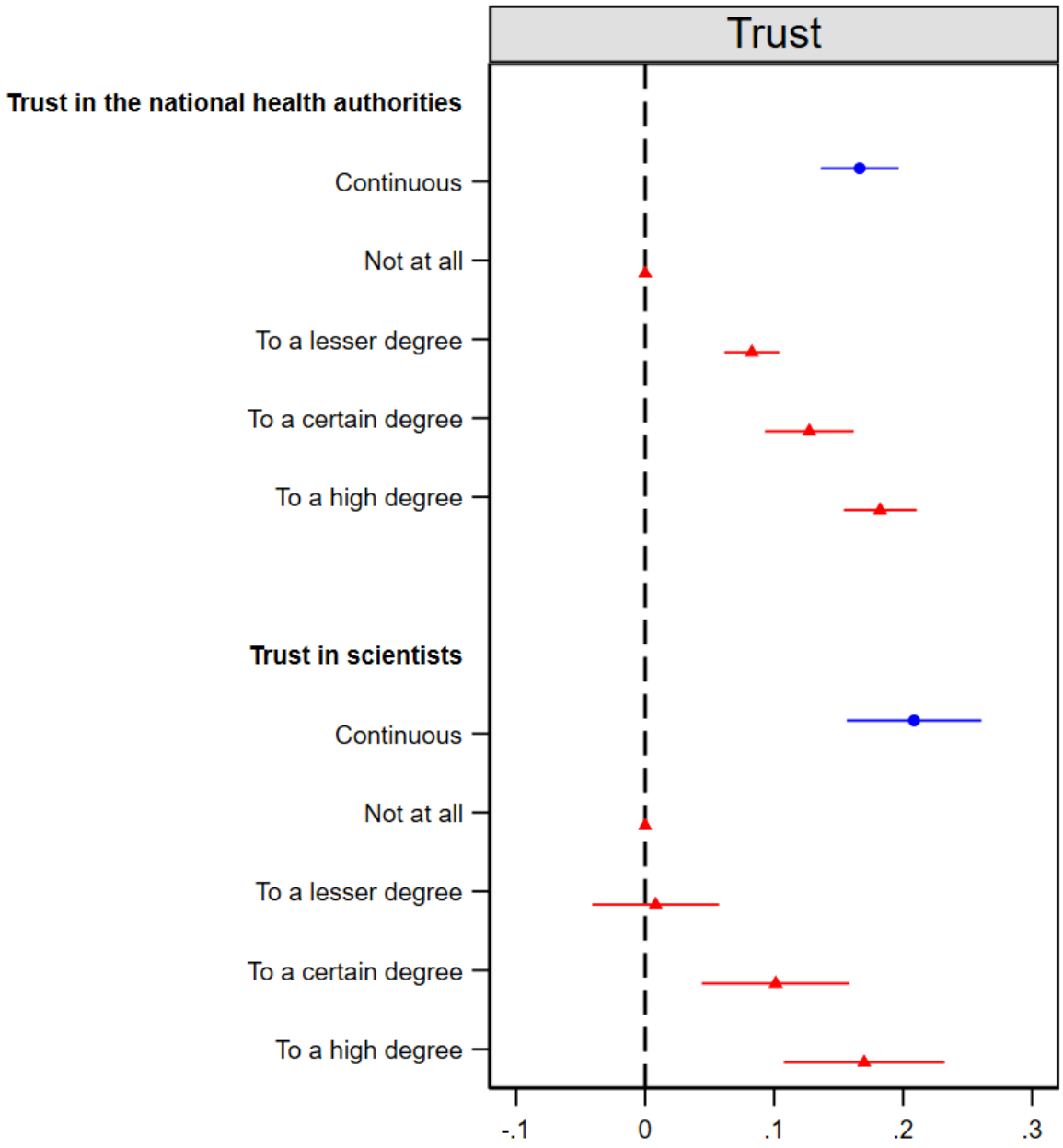
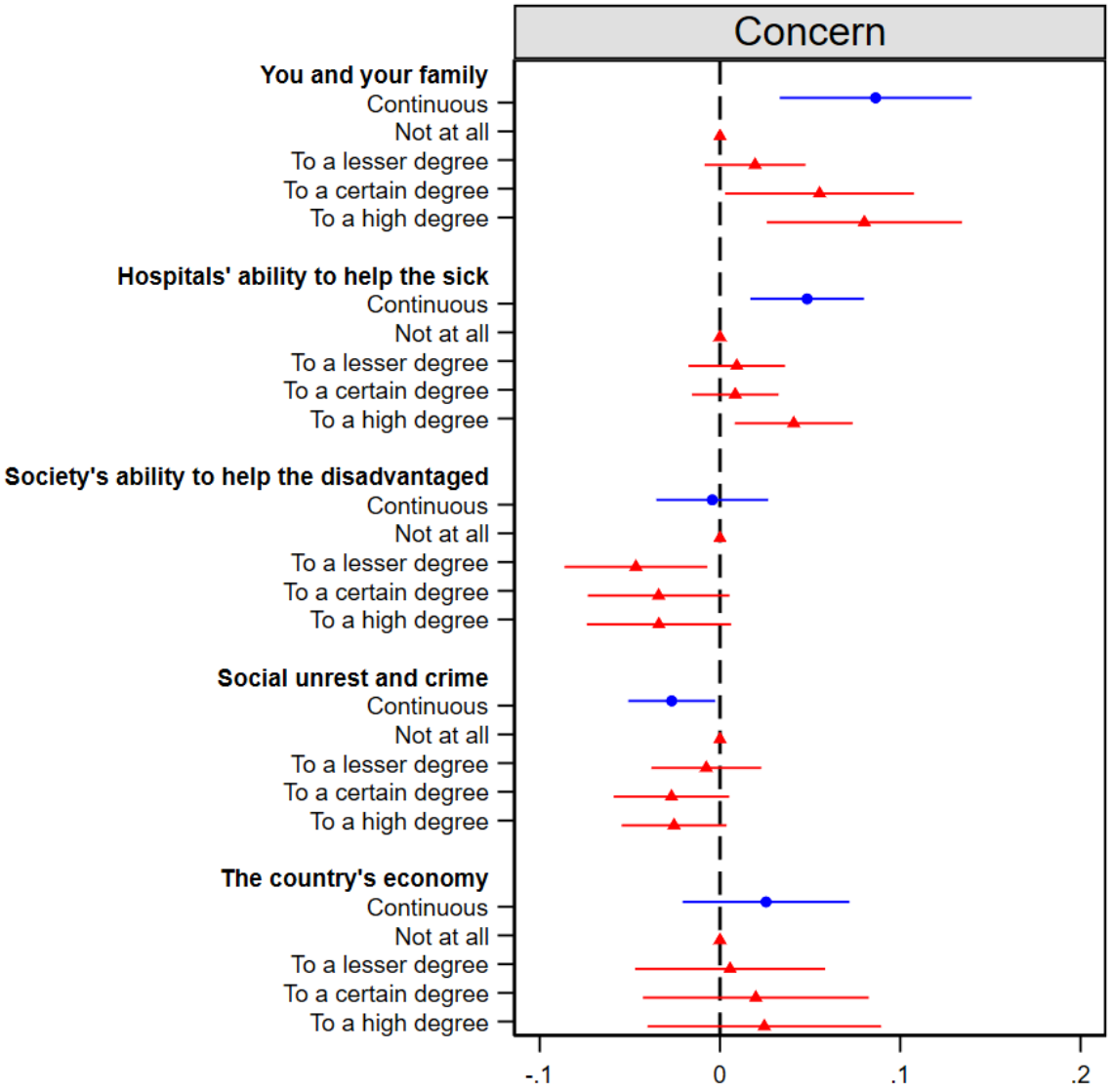


Figure A2: Replicating the analysis with categorical trust variables



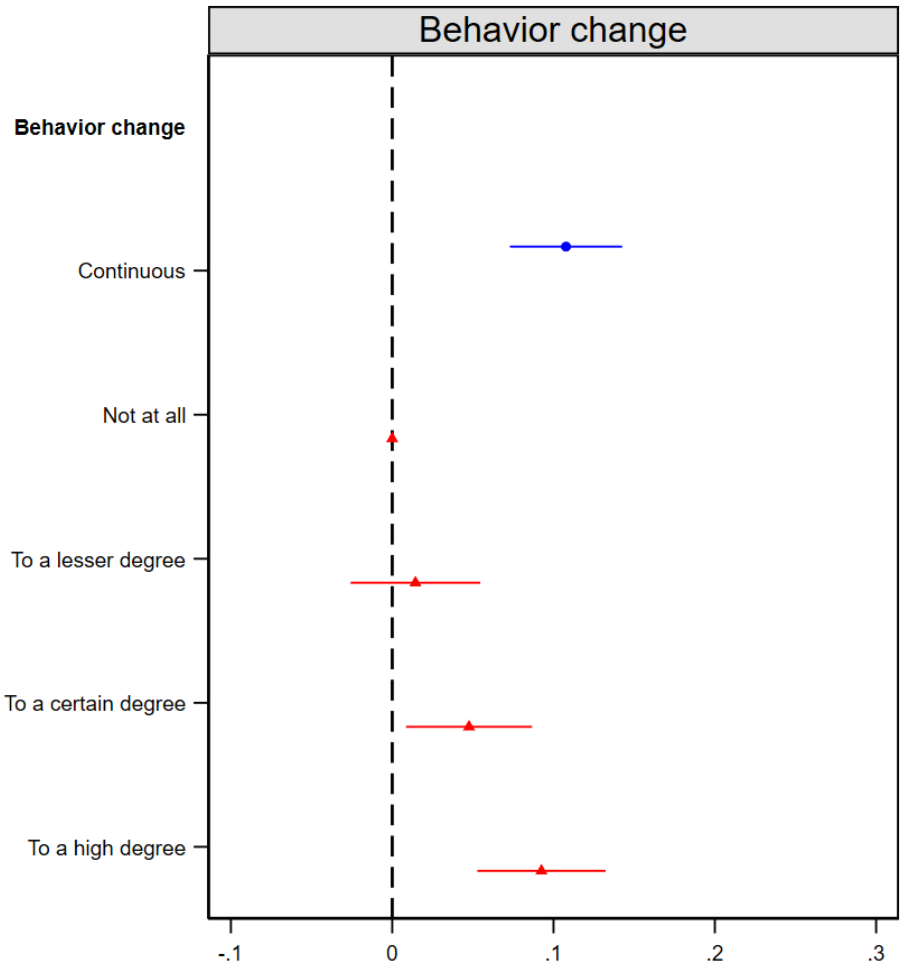
Note: N = 18,231. Blue circles are the estimated correlations based on model II in Table A4 (continuous trust variables). Red triangles are the estimated correlations based on the same model, using categorical trust variables instead. Both models include control for country dummies. Horizontal lines are the associated 95 % confidence intervals.

Figure A3: Replicating the analysis with categorical concern variables



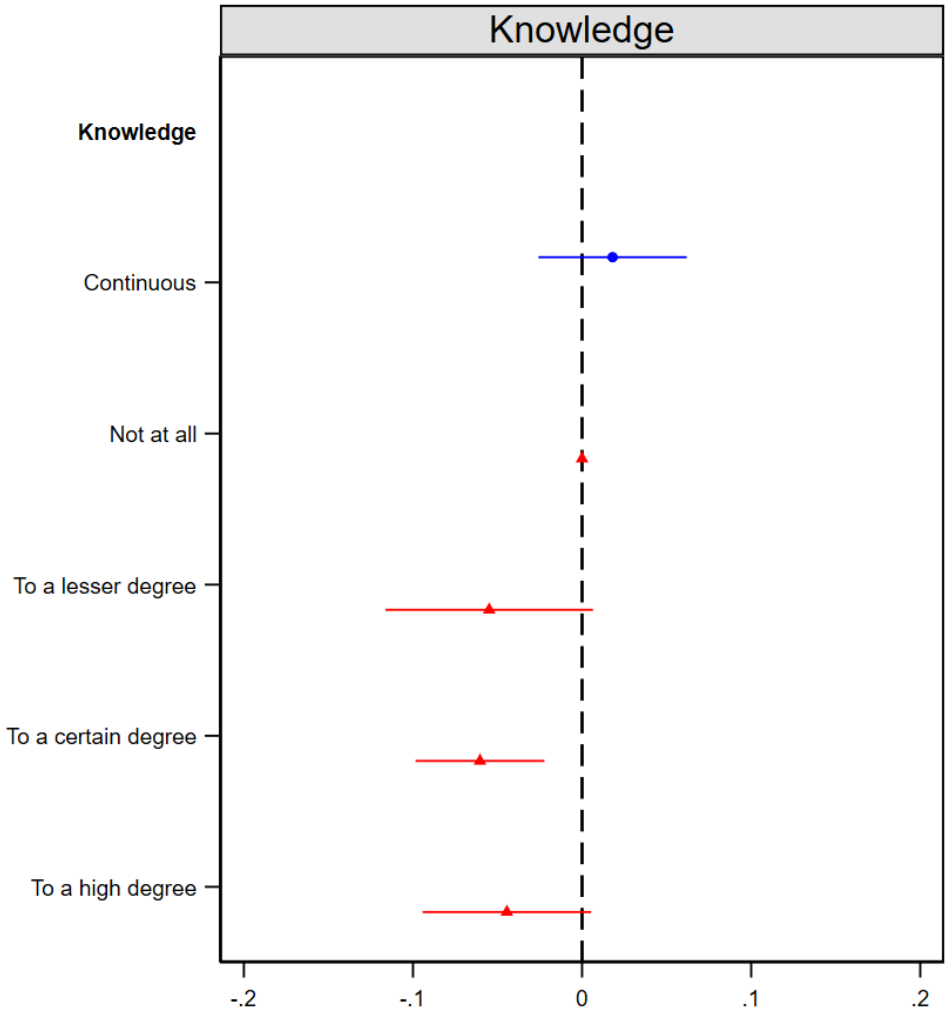
Note: N =18,231. Blue circles are the estimated correlations based on model II in Table A4 (continuous concern variables). Red triangles are the estimated correlations based on the same model, using categorical concern variables instead. Both models include control for country dummies. Horizontal lines are the associated 95 % confidence intervals.

Figure A4: Replicating the analysis with a categorical behavior change variable



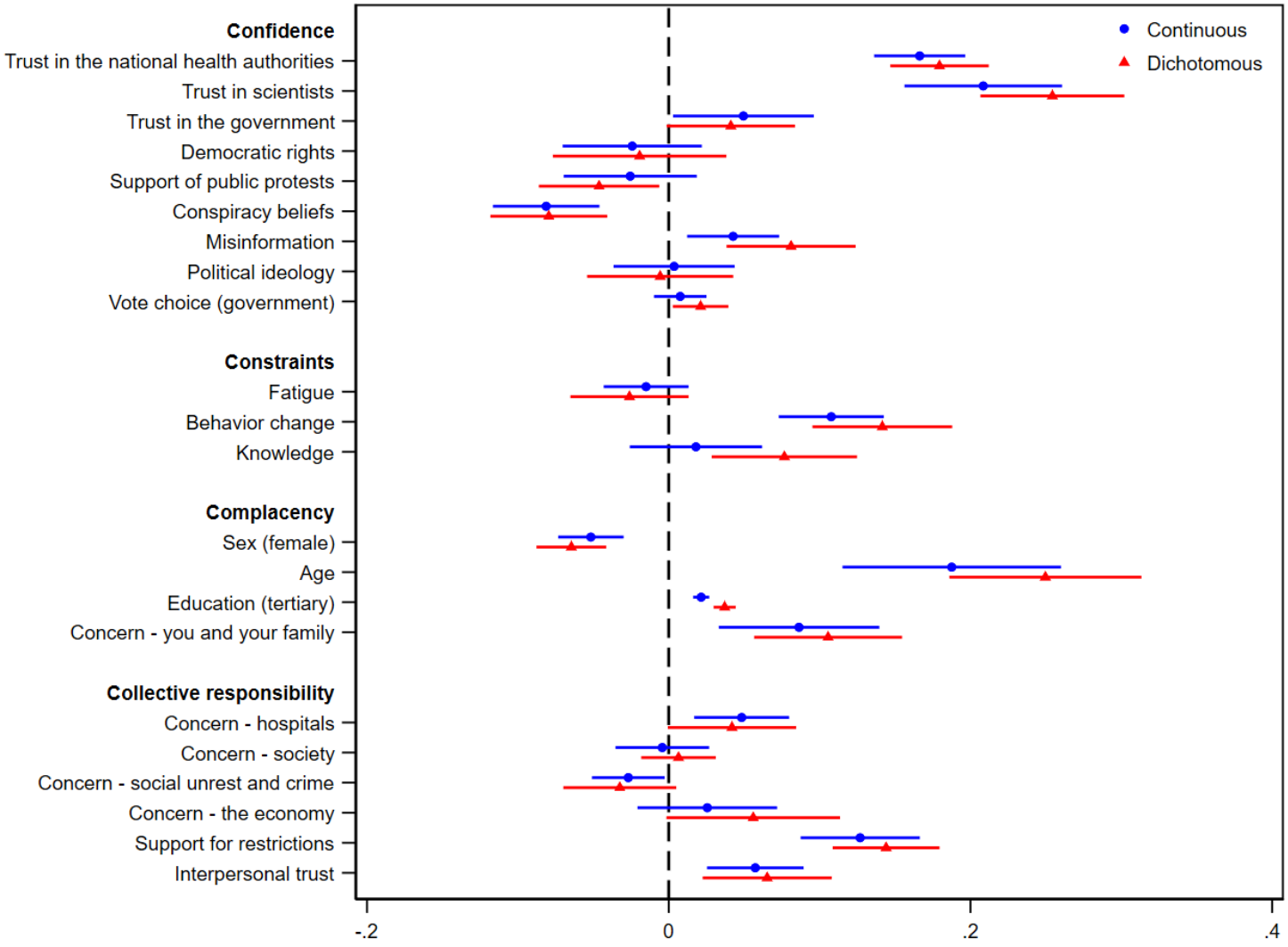
Note: N = 18,231. Blue circles are the estimated correlations based on model II in Table A4 (continuous behavior change variable). Red triangles are the estimated correlations based on the same model, using a categorical behavior change variable instead. Both models include control for country dummies. Horizontal lines are the associated 95 % confidence intervals.

Figure A5: Replicating the analysis with a categorical knowledge variable



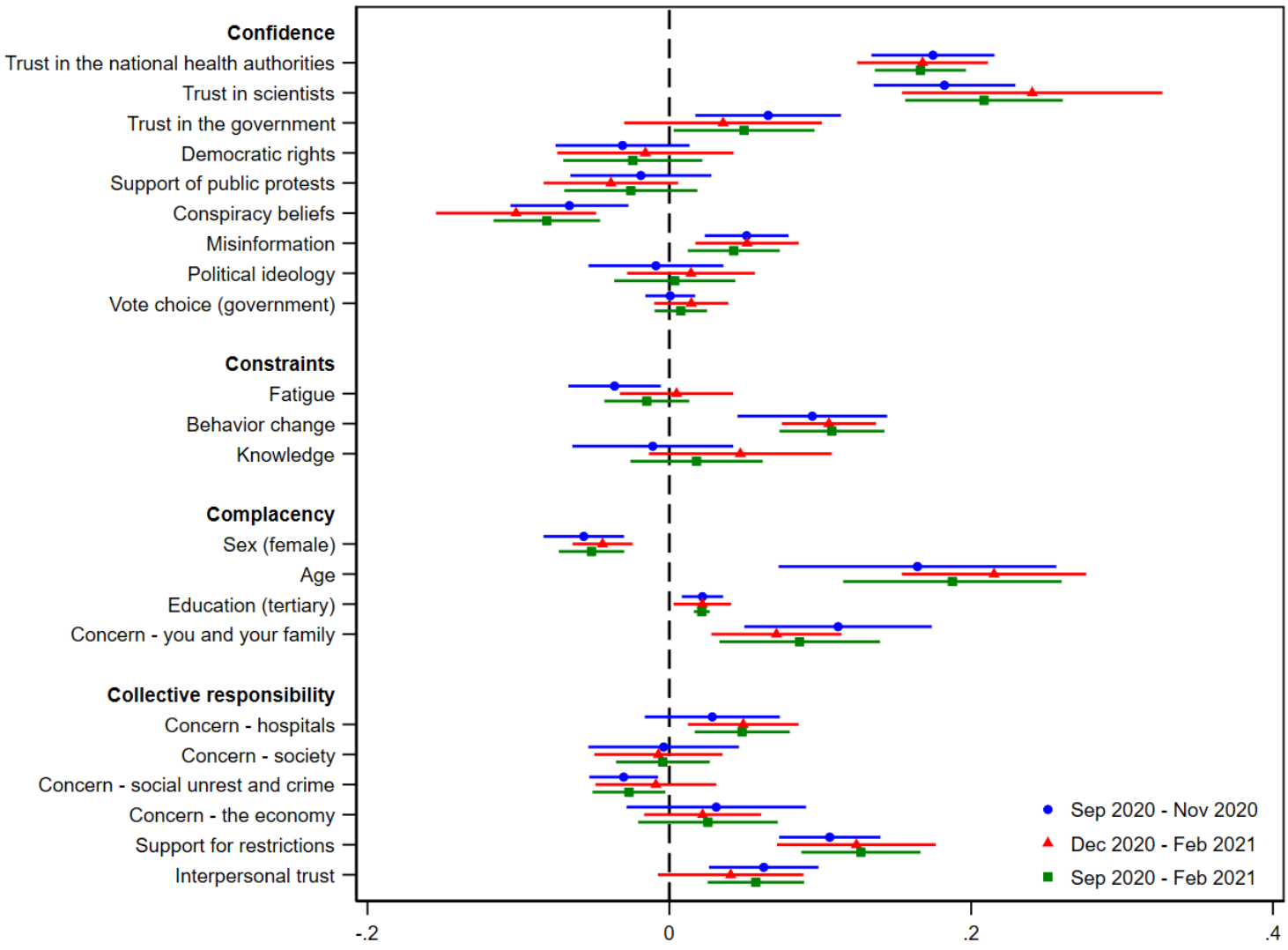
Note: N = 18,231. Blue circles are the estimated correlations based on model II in Table A4 (continuous knowledge variable). Red triangles are the estimated correlations based on the same model, using a categorical knowledge variable instead. Both models include control for country dummies. Horizontal lines are the associated 95 % confidence intervals.

Figure A6: Replicating the analysis with a dichotomous vaccine acceptance outcome



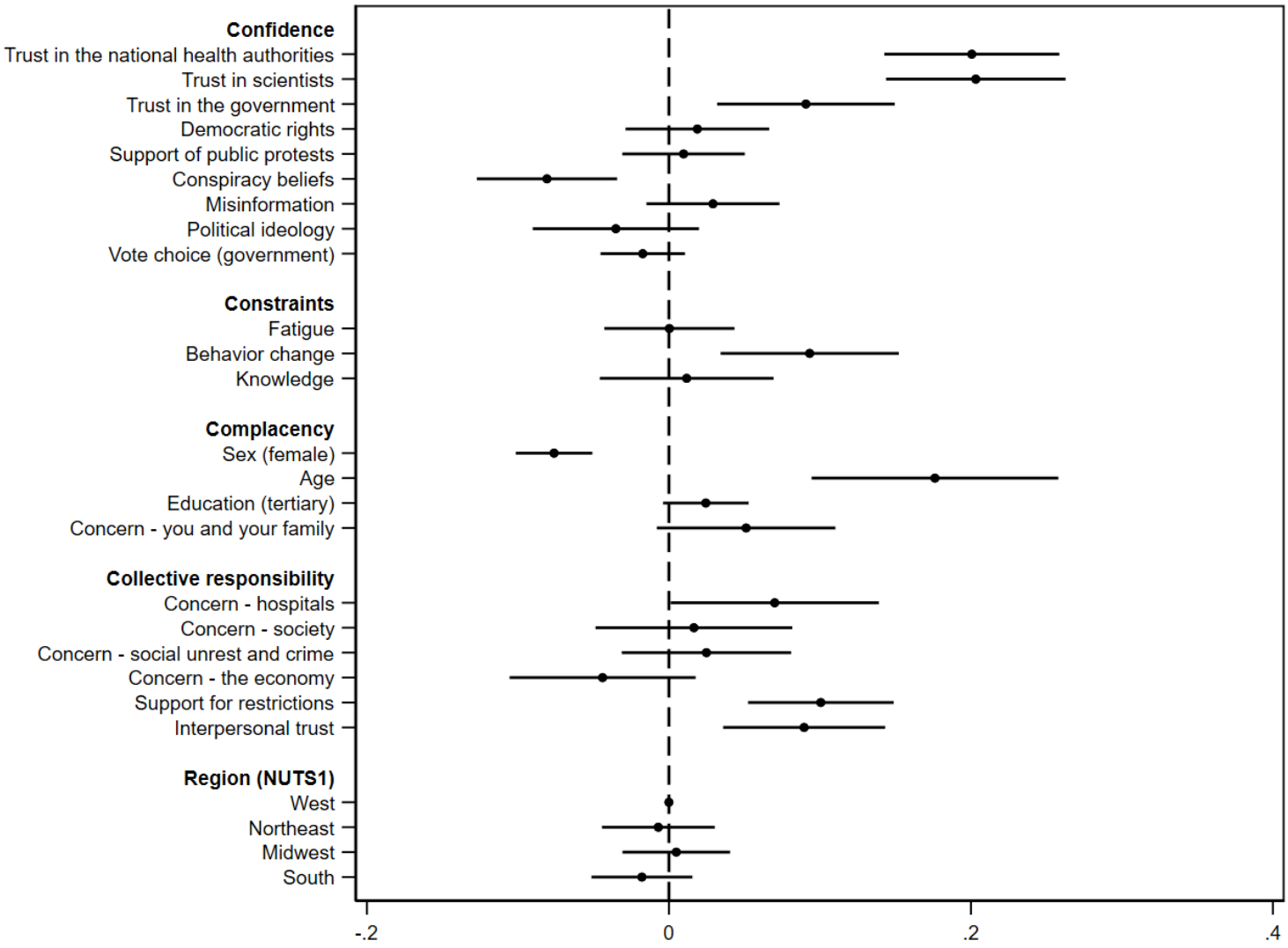
Note: N = 18,231. Blue circles are the estimated correlations based on model II in Table A4 (continuous outcome). Red triangles are the estimated correlations based on the same model, using a dichotomous measure of vaccine acceptance instead (with "somewhat agree" and "completely agree" taking the value 1, indicating vaccine acceptance). Both models include control for country dummies. Horizontal lines are the associated 95 % confidence intervals.

Figure A7: Comparing results before and after approval of COVID-19 vaccines



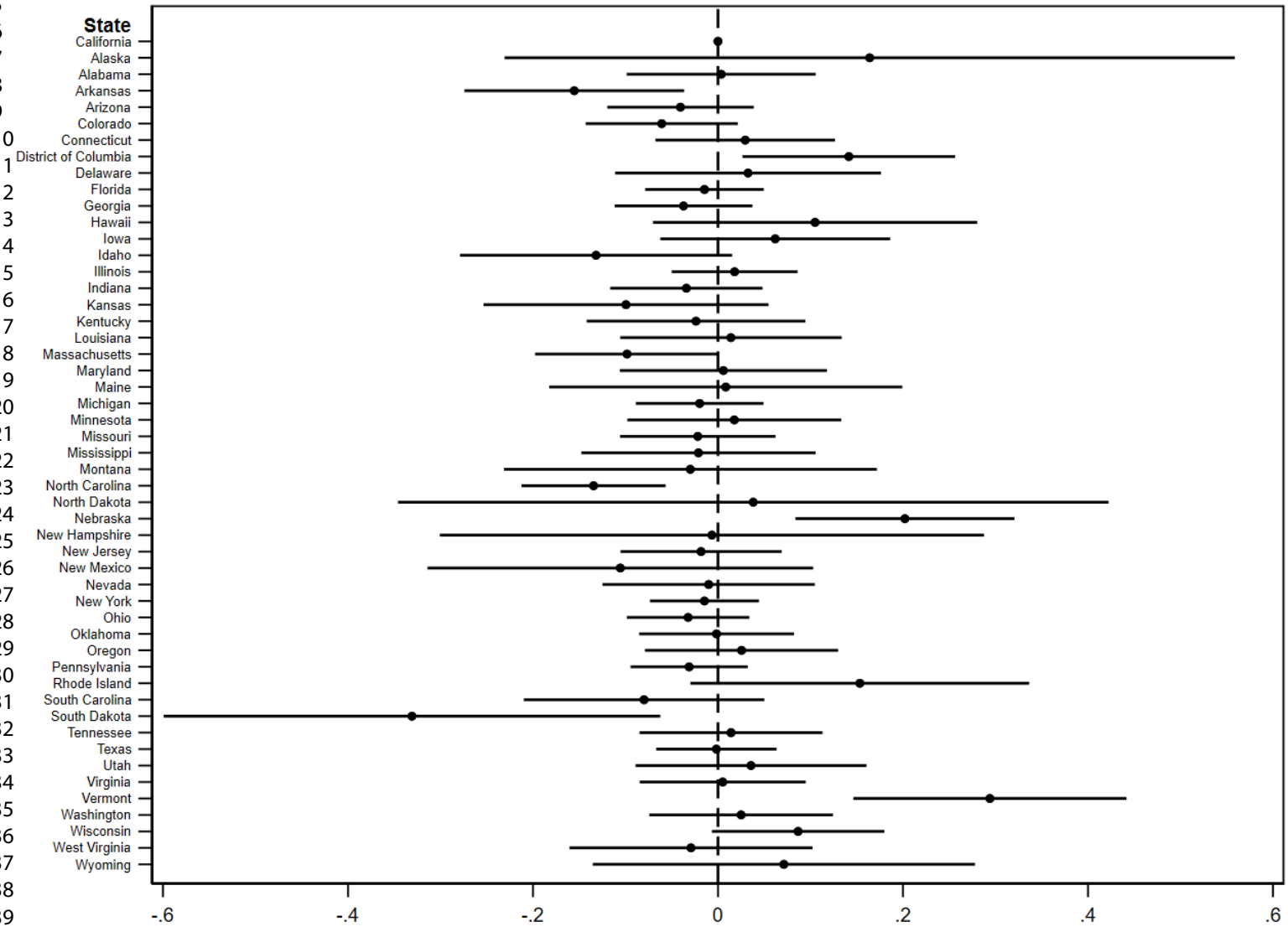
Note: N = 10,417 (September 2020 – November 2020). N = 7,814 (December 2020 – February 2021). N = 18,231 (September 2020 – February 2021). Green squares are the estimated correlations based on model II in Table A4 (September 2020 - November 2020). Blue circles are the estimated correlations based on the same model for September 2020 – November 2020. Red triangles are the estimated correlations based on the same model for December 2020 – February 2021. All models include control for country dummies. Horizontal lines are the associated 95 % confidence intervals.

Figure A8: Individual-level predictors in the US, controlling for region dummies



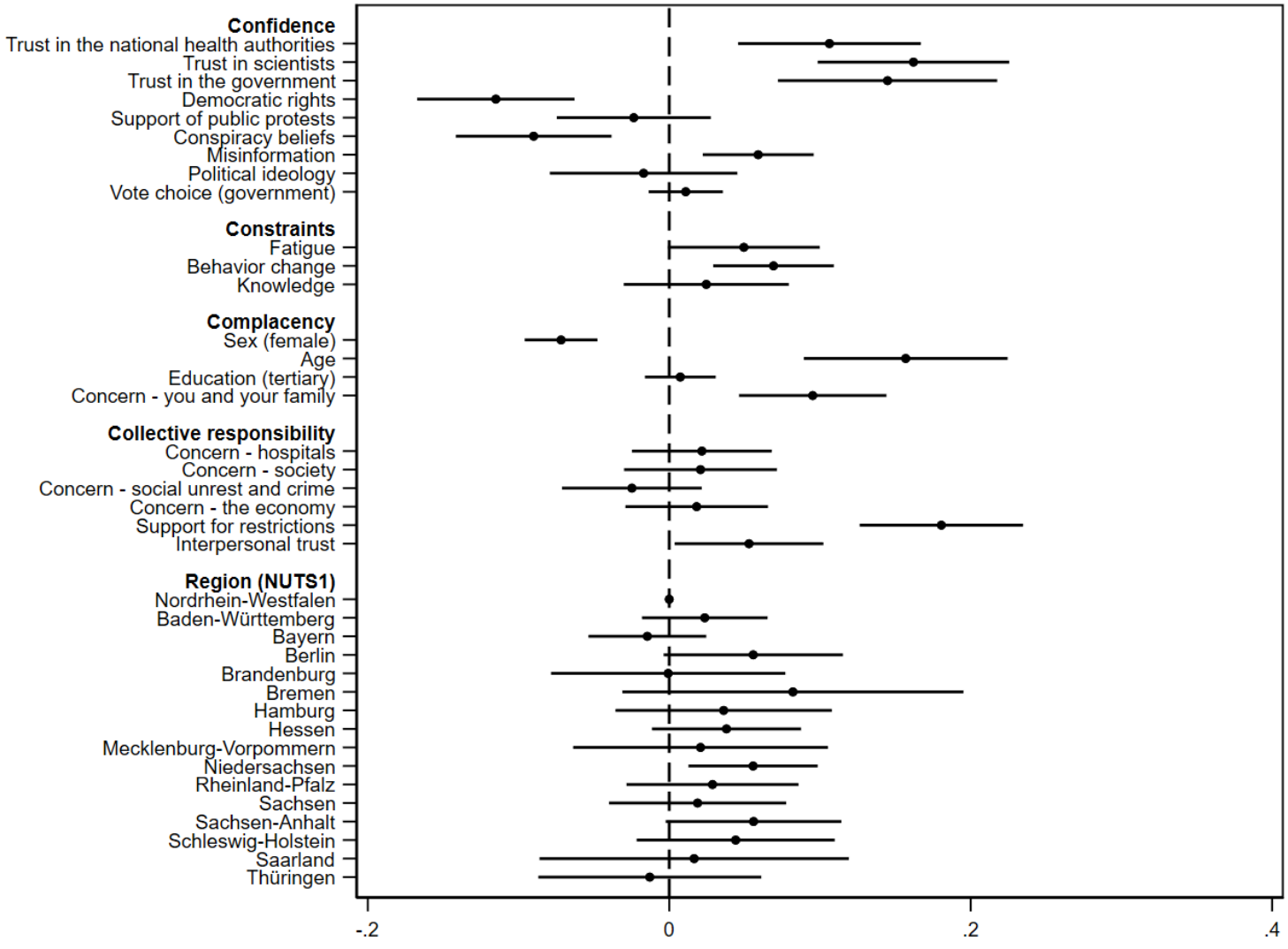
Note: N = 2,185. Circles are the estimated correlations. Horizontal lines are the associated 95 % confidence intervals.

Figure A9: Individual-level predictors in the US, controlling for state dummies



Note: N = 2,185. Circles are the estimated correlations. The model include all predictors from model II in table A4, controlling for state dummies instead of country level dummies. For simplicity, only the estimated correlations for the state dummies are illustrated here. Horizontal lines are the associated 95 % confidence intervals.

Figure A10: Individual-level predictors in Germany, controlling for state dummies



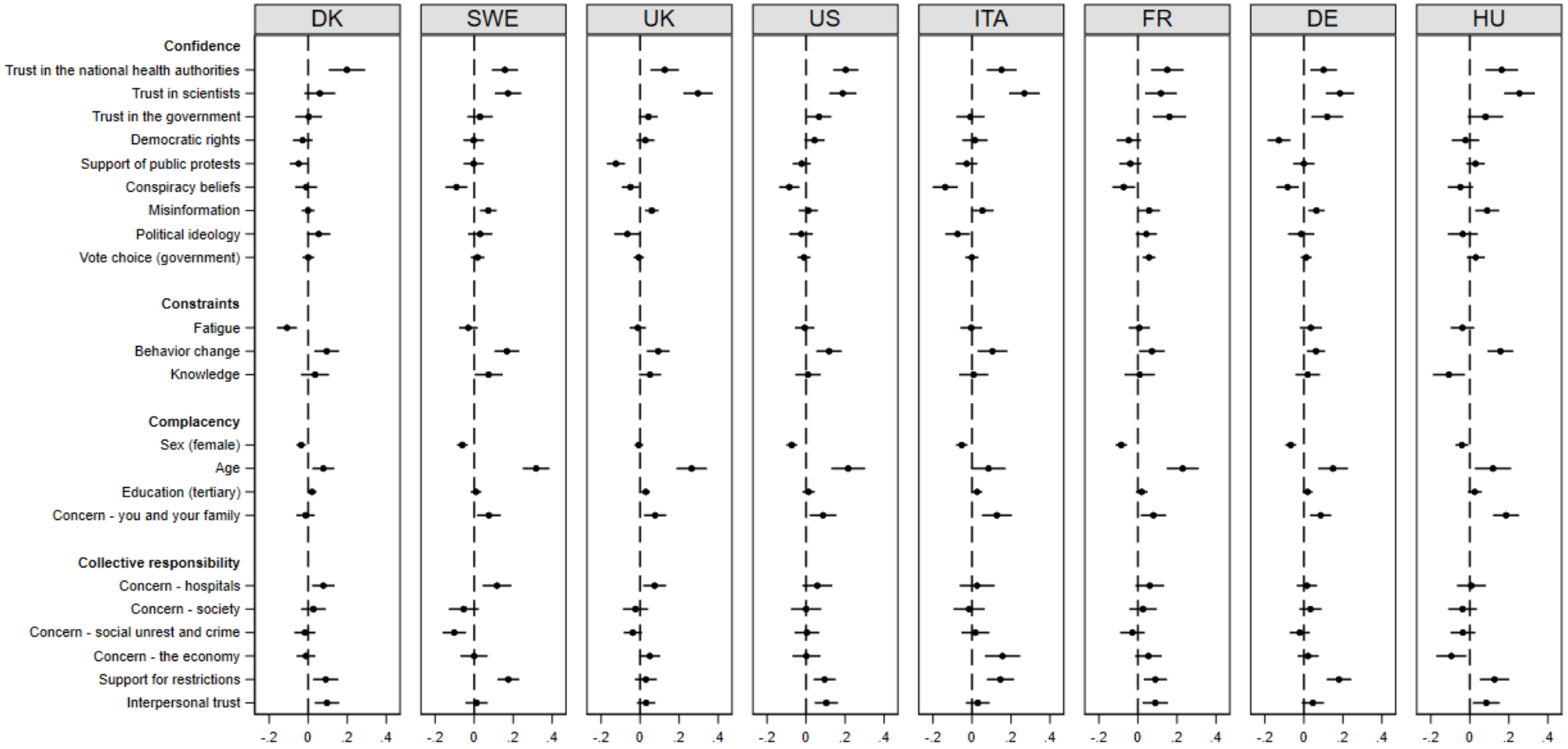
Note: N = 2,380. Circles are the estimated correlations. Horizontal lines are the associated 95 % confidence intervals.

Table A4: Individual-level predictors of vaccine acceptance

	Model I Bivariate		Model VI Full model	
Confidence				
Trust in health authorities	0.498***	(0.008)	0.166***	(0.013)
Trust in scientists	0.531***	(0.009)	0.208***	(0.022)
Trust in the government	0.344***	(0.008)	0.050*	(0.020)
Concern about democratic rights	-0.256***	(0.007)	-0.024	(0.020)
Support for protests	-0.224***	(0.007)	-0.026	(0.019)
Conspiracy beliefs	-0.297***	(0.007)	-0.081***	(0.015)
Misinformation	0.017*	(0.008)	0.043*	(0.013)
Ideology	-0.115***	(0.009)	0.004	(0.017)
Vote choice (government)	0.078***	(0.005)	0.008	(0.007)
Constraints				
Fatigue	-0.189***	(0.007)	-0.015	(0.012)
Behavior change	0.312***	(0.009)	0.108***	(0.015)
Knowledge	0.232***	(0.011)	0.018	(0.019)
Complacency				
Sex (female)	-0.046***	(0.005)	-0.052***	(0.009)
Age	0.231***	(0.013)	0.188***	(0.031)
Education (tertiary)	0.049***	(0.005)	0.022***	(0.002)
Concern - you and your family	0.173***	(0.009)	0.086**	(0.023)
Collective responsibility				
Concern - hospitals	0.137***	(0.009)	0.048**	(0.013)
Concern - society	0.099***	(0.009)	-0.004	(0.013)
Concern - social unrest and crime	-0.049***	(0.008)	-0.027*	(0.010)
Concern - the country's economy	0.003	(0.010)	0.026	(0.020)
Support for restrictions	0.334***	(0.009)	0.127***	(0.017)
Interpersonal trust	0.204***	(0.009)	0.057**	(0.014)
Constant			-0.034	(0.025)
Observations	18,231		18,231	
R^2	NA		0.322	

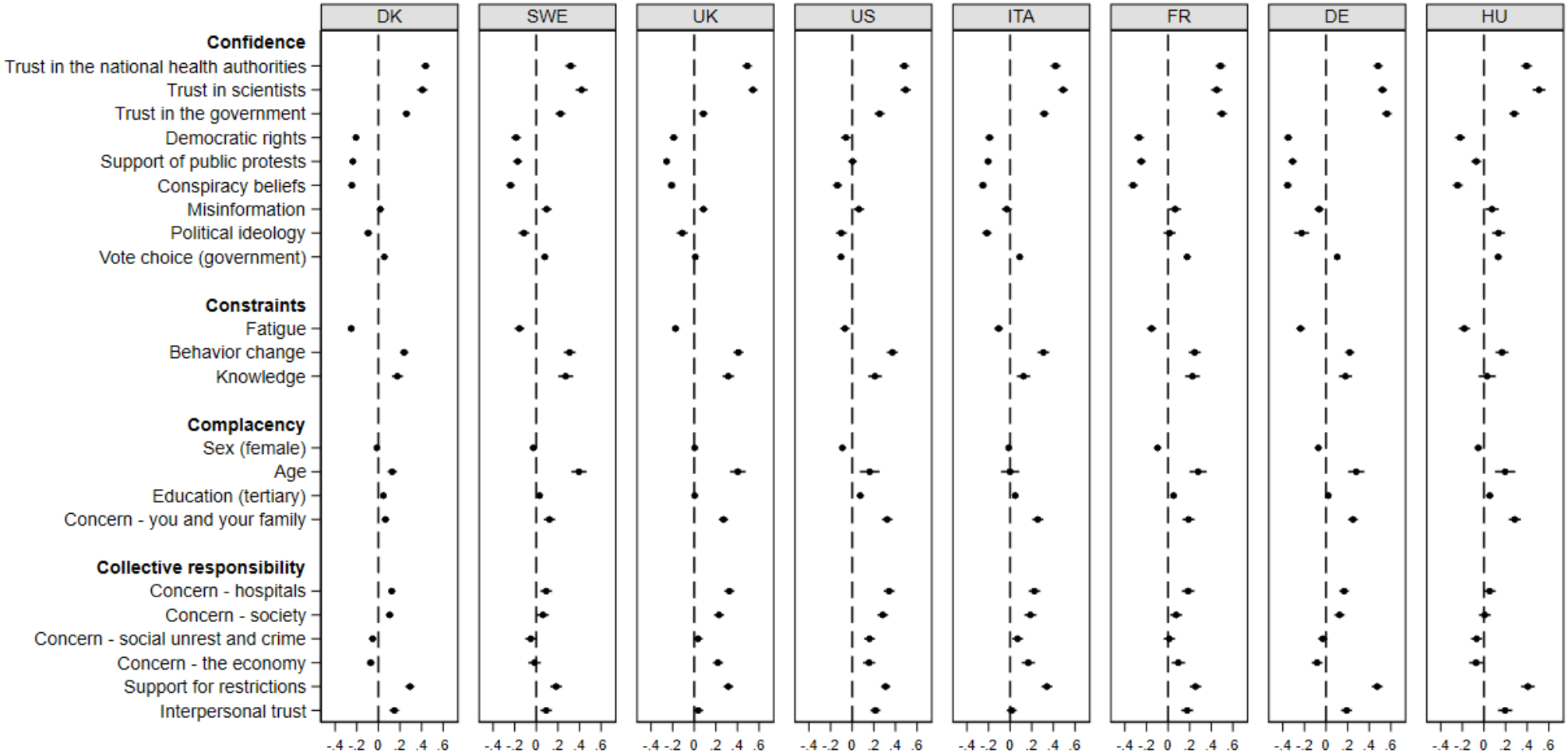
Notes. Entries are unstandardized OLS regression coefficients from models with all variables standardized on a scale from 0-1. Clustered robust standard errors on country level in parentheses. Model 1 displays effects from bivariate models and, hence, a combined R^2 cannot be computed. Model II includes control for country dummies. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Figure A11: Individual-level correlations of vaccine acceptance by country



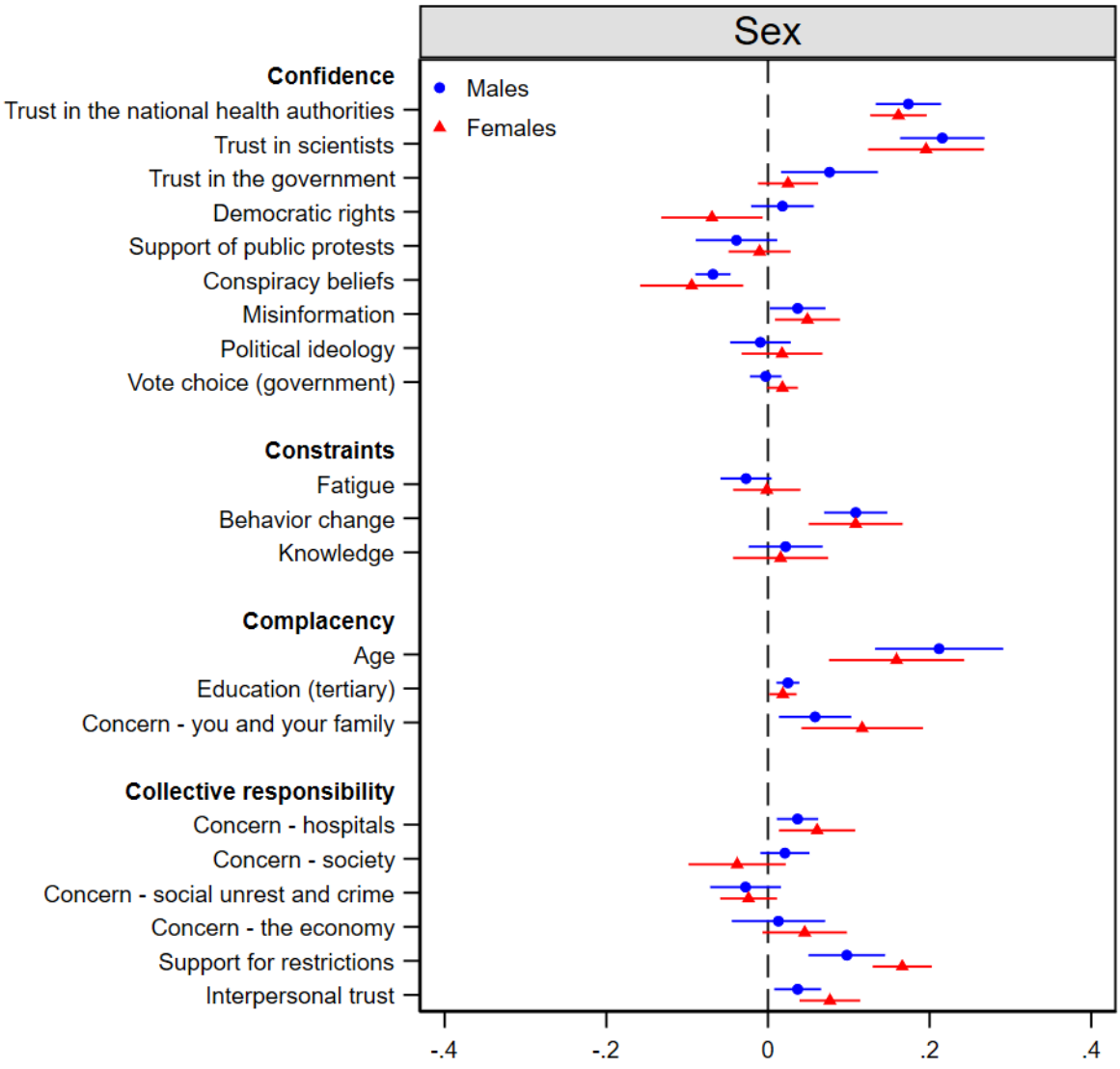
Note: N = 18,231. Black circles are the estimated correlations. Horizontal bars are the associated 95 % confidence intervals.

Figure A12: Bivariate correlations by country



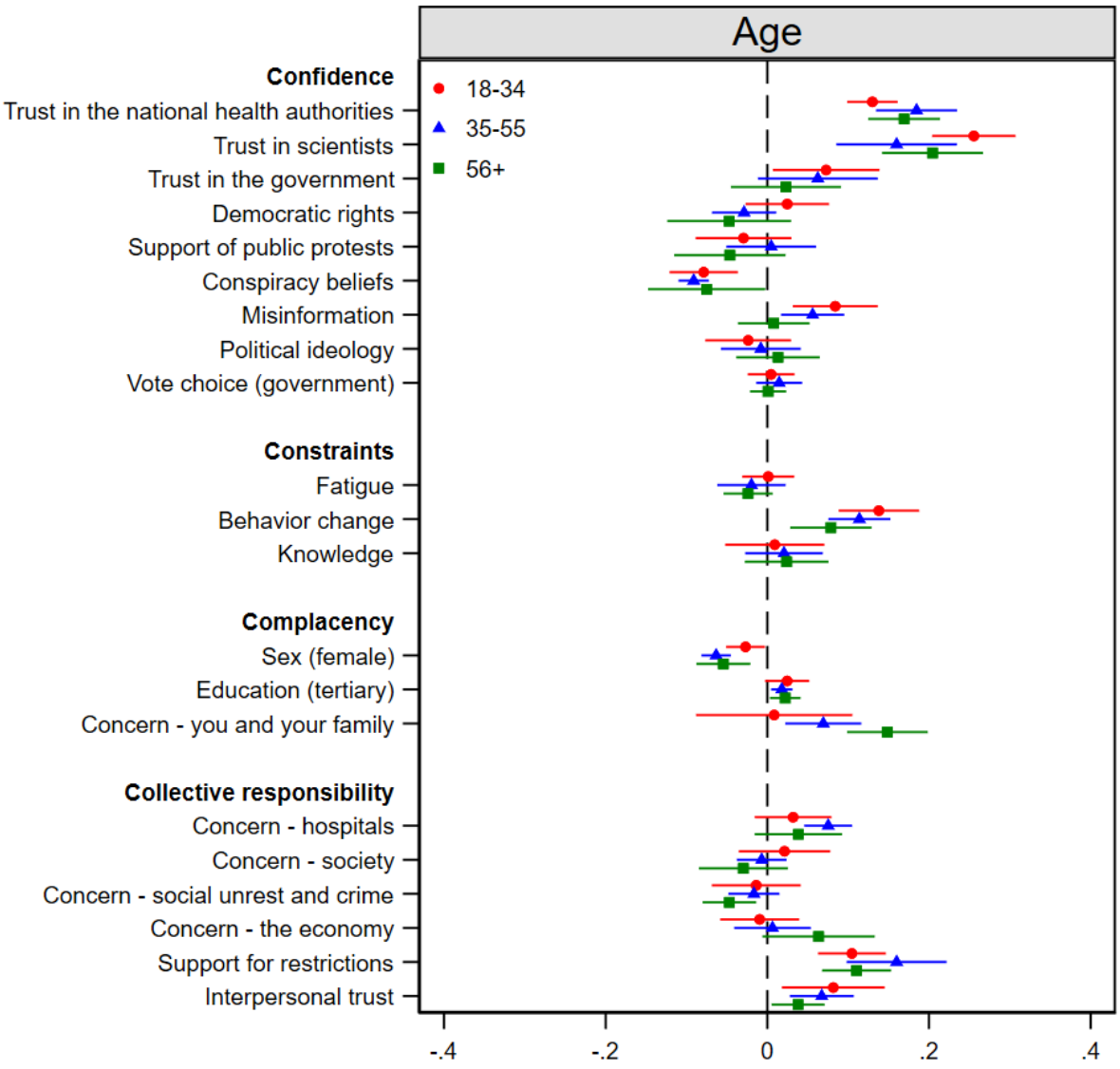
Note: N = 18,231. Black circles are the estimated bivariate correlations. Horizontal bars are the associated 95 % confidence intervals.

Figure A13: Subgroup analysis – sex



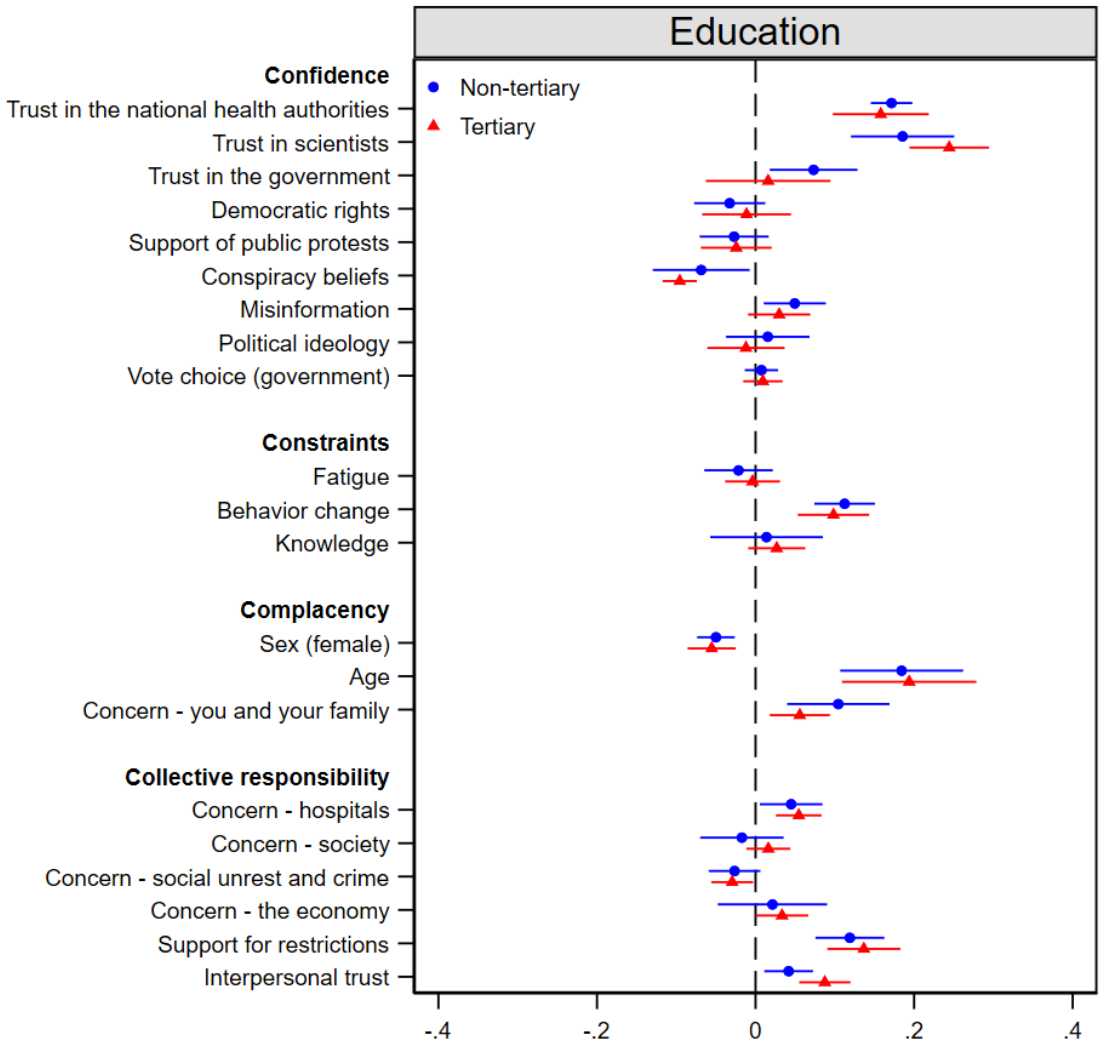
Note: N = 18,231. Blue circles and red triangles are the estimated correlations. Horizontal lines are the associated 95 % confidence intervals.

Figure A14: Subgroup analysis – age



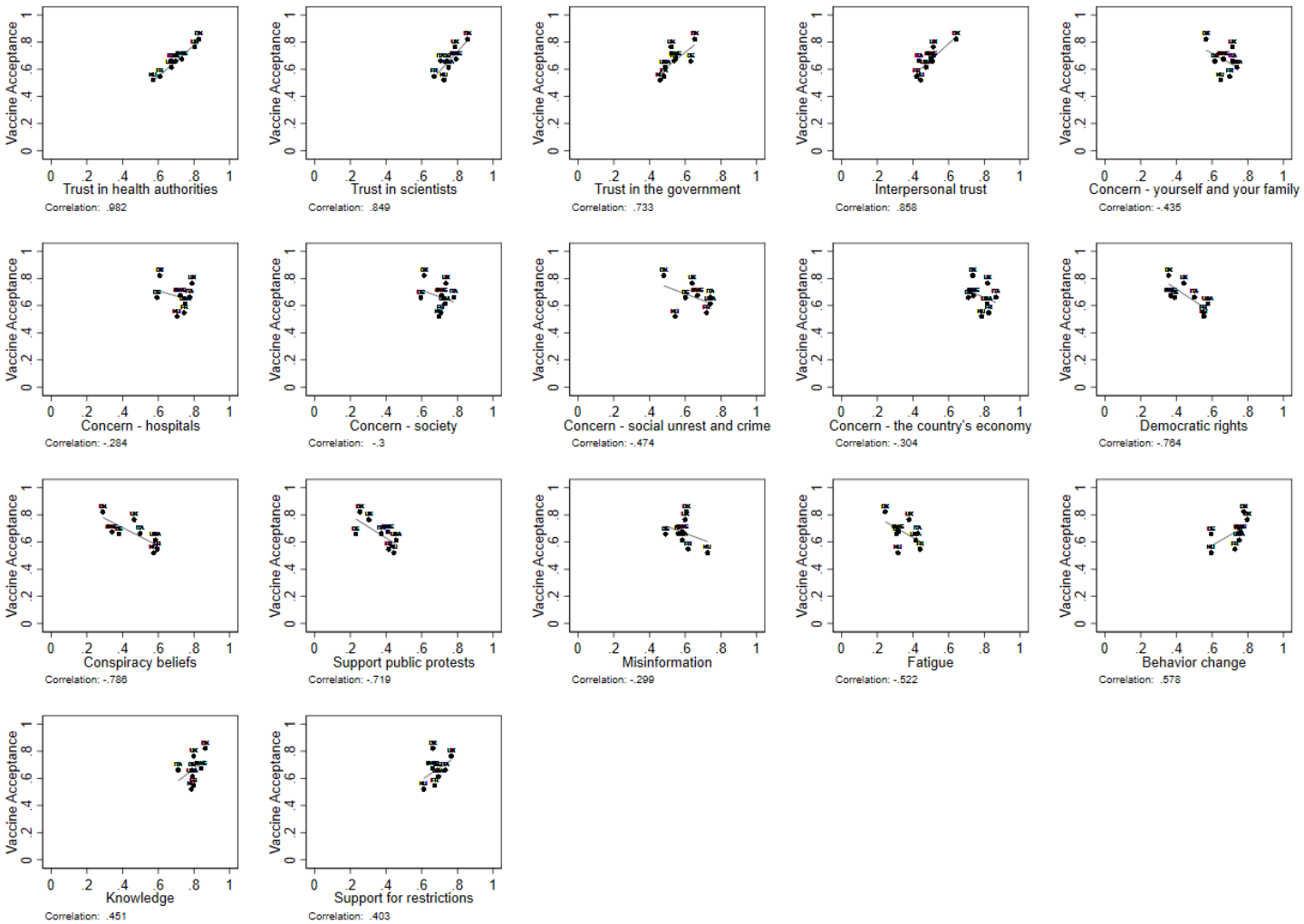
Note: N = 18,231. Red circles, blue triangles and green squares are the estimated correlations. Horizontal lines are the associated 95 % confidence intervals.

Figure A15: Subgroup analysis – education



Note: N = 18,231. Blue circles and red triangles are the estimated correlations. Horizontal lines are the associated 95 % confidence intervals.

Figure A16: Macro-level correlations of vaccine acceptance



Note: The figure plots country averages for vaccine acceptance and country averages for the range of non-background measures. Reported correlations are pearson's r.

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	0
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	1
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	7-8
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	7-8
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	7-8
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	8-12
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	8-12
Bias	9	Describe any efforts to address potential sources of bias	
Study size	10	Explain how the study size was arrived at	7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	11-12
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	12-13
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	12
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	12-13
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	2 + Table A1 in the OA
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Table A2 in the OA
		(b) Indicate number of participants with missing data for each variable of interest	
Outcome data	15*	Report numbers of outcome events or summary measures	11 + Figure 1
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	14-16 + Figure 2 + Table A4 in the OA
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	16 + OA
Discussion			
Key results	18	Summarise key results with reference to study objectives	16-17
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	18
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	
Generalisability	21	Discuss the generalisability (external validity) of the study results	18
Other information			16-19
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	2

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.