

Kent Academic Repository

Full text document (pdf)

Citation for published version

Rutjens, Bastiaan T. and Sengupta, Nikhil Kumar and van der Lee, Romy and van Koningsbruggen, Guido M. and Martens, Jason P. and Rabelo, André and Sutton, Robbie M. (2021) Science skepticism across 24 countries. *Social Psychological and Personality Science*. ISSN 1948-5506. (In press)

DOI

Link to record in KAR

<https://kar.kent.ac.uk/87366/>

Document Version

Author's Accepted Manuscript

Copyright & reuse

Content in the Kent Academic Repository is made available for research purposes. Unless otherwise stated all content is protected by copyright and in the absence of an open licence (eg Creative Commons), permissions for further reuse of content should be sought from the publisher, author or other copyright holder.

Versions of research

The version in the Kent Academic Repository may differ from the final published version.

Users are advised to check <http://kar.kent.ac.uk> for the status of the paper. **Users should always cite the published version of record.**

Enquiries

For any further enquiries regarding the licence status of this document, please contact:

researchsupport@kent.ac.uk

If you believe this document infringes copyright then please contact the KAR admin team with the take-down information provided at <http://kar.kent.ac.uk/contact.html>

AUTHOR'S ACCEPTED MANUSCRIPT. ARTICLE ACCEPTED FOR PUBLICATION AT *SOCIAL PSYCHOLOGICAL AND PERSONALITY SCIENCE* (<https://journals.sagepub.com/home/spp>). FINAL PUBLISHED VERSION MAY VARY. TO CITE Rutjens, B. T., Sengupta, N., van der Lee, R., van Koningsbruggen, G. M., Martens, J. P., Rabelo, A., & Sutton, R. M. (2021). Science skepticism across 24 countries. *Social Psychological & Personality Science*.

Science skepticism across 24 countries

Bastiaan T. Rutjens

University of Amsterdam

Nikhil Sengupta

University of Kent

Romy van der Lee

Vrije Universiteit Amsterdam

Guido M. van Koningsbruggen

Vrije Universiteit Amsterdam

Pontificia Universidad Católica de Chile

Jason P. Martens

Capilano University

André Rabelo

Universidade de Brasília

Robbie M. Sutton

University of Kent

Please address correspondence to Bastiaan T. Rutjens, University of Amsterdam (e-mail:

b.t.rutjens@uva.nl)

Acknowledgment: This research was funded by an EASP Seedcorn grant awarded to BTR and RVDL and a grant by the Institute for Societal Resilience (ISR) awarded to RvdL, BTR, and GMvK.

Abstract

Efforts to understand and remedy the rejection of science are impeded by lack of insight into how it varies in degree and in kind around the world. The current work investigates science skepticism in 24 countries ($N = 5973$). Results show that while some countries stand out as generally high or low in skepticism, predictors of science skepticism are relatively similar across countries. One notable effect was consistent across countries though stronger in WEIRD nations: General faith in science was predicted by spirituality, suggesting that it, more than religiosity, may be the 'enemy' of science acceptance. Climate change skepticism was mainly associated with political conservatism, especially in North America. Other findings were observed across WEIRD and non-WEIRD nations: Vaccine skepticism was associated with spirituality and scientific literacy, GM skepticism with scientific literacy, and evolution skepticism with religious orthodoxy. *Levels* of science skepticism are heterogeneous across countries, but *predictors* of science skepticism are heterogeneous across domains.

Science is an integral part of modern life. However, the historical authority of science can no longer be taken for granted¹⁻³. Systematic and unwarranted rejection of science—i.e., *science skepticism*—has become a major societal problem that can have severely damaging effects on individuals and societies. To illustrate, two of the World Health Organization’s top 10 health threats for 2019 are firmly rooted in science skepticism: *climate change* and *vaccine hesitancy*. The latter is a particularly poignant example of the risks of science skepticism for public health, with insufficient vaccination rates leading to various measles outbreaks in 2017 and 2018 and documented increases in measles cases in various countries across the globe⁴. Vaccine hesitancy might also obstruct the probability of success of future public vaccination campaigns against Covid-19^{26,27}.

But are skepticism about climate change and vaccination shaped by the same causes? Recent work has shown that this is not so. Instead, evidence has started to accumulate for the “heterogeneity of science skepticism”^{1,2,5,6}. This heterogeneity pertains both to the *predictors* of science skepticism and to the *domains* of science skepticism: Skepticism is shaped by varying beliefs and ideologies, and the effects of each is contingent on the domain (the most widely researched domains are climate change, vaccination, genetic modification, and evolution). For example, climate change skepticism is primarily associated with political ideology, but not with religious or spiritual beliefs, whereas vaccination skepticism shows the opposite pattern^{1,2,5}.

In addition to the relative importance of different predictors across different domains, a third potential strand of heterogeneity concerns potential cultural differences in science skepticism and its predictors. After all, a growing body of research shows that human beings are fundamentally a cultural species, so that many psychological differences (e.g., attitudes and beliefs) are rooted in cultural differences²⁴. Importantly, to our knowledge, the limited evidence for the heterogeneity of science skepticism comes only from studies conducted in the US^{1,6} and the Netherlands², which are both WEIRD countries (Western, Educated, Industrialized, Rich, and Democratic^{7,8,24}). Although other research^{9,10} has tested predictors of skepticism across countries, it has some important limitations, including being focused on one science domain only (i.e., vaccination⁹, climate change¹⁰), and excluding measures of belief which have been found to play a substantial role in shaping science skepticism (i.e., religiosity and spirituality)^{1,2,5,11}. To obtain a more complete picture of the heterogeneous nature of science skepticism, it is crucial to test the broadest range of previously observed predictors across both WEIRD and non-WEIRD nations, and across multiple domains of science.

In sum, a systematic cross-national investigation of the relative impact of various potential predictors of science skepticism as manifested across domains is lacking. The main goal of the current research is to fill this gap and provide the foundation of a much-needed comprehensive research program that not only synthesizes previous work but also provides a crucial test of its generalizability across societies. In order to do so, we tested predictors of science skepticism about climate change, vaccination, genetic modification (GM), evolution, and general faith in science in 24 countries across the globe.

The overarching hypothesis guiding the current research is that science skepticism is heterogeneous. We expect this heterogeneity to occur both within countries—such that different predictors are associated with science skepticism in different domains—but also between them, such that some patterns of association differ across countries. Based on previous work on the antecedents of science skepticism^{1,2,5,9,10} we additionally formulated a set of more specific hypotheses (see Table 1 for hypotheses), bearing in mind the caveat that previous research investigated these antecedents within a WEIRD (mostly Anglo-Saxon) cultural context. We did not formulate *a priori* hypotheses for predicting willingness to support science, because previous research yielded mixed results with some studies showing effects similar to those for faith in science - religious orthodoxy predicting science support in the USA, spirituality predicting science support in the Netherlands - and other studies only showing effects of faith in science on willingness to support science. Finally, we predicted several country-level differences. Hypothesis 1a is based on recent work on climate change attitudes and political ideology¹⁰. The remaining country-level differences that we hypothesized pertain specifically to potentially different effects of spirituality and traditional religiosity (operationalized as religious orthodoxy) in secularized Western (WEIRD) nations versus non-WEIRD nations—that have generally not undergone similar secularization processes—on science skepticism.

Although we had access to community samples from roughly 12.5% of the world's countries, we were able to cover all continents except Antarctica (see Figure 1), including various countries that are largely absent from the psychological science database^{8,24,30}. The current research includes the following countries: Australia ($N = 315$), Belgium ($N = 344$), Brazil ($N = 236$), Canada ($N = 232$), China ($N = 169$), Egypt ($N = 247$), France ($N = 214$), Germany ($N = 269$), Iran ($N = 239$), Israel ($N = 247$), Italy ($N = 295$), North Macedonia ($N = 214$), Mexico ($N = 225$), Morocco ($N = 186$), the Netherlands ($N = 264$), Poland ($N = 244$), Portugal ($N = 252$), Romania ($N = 196$), Sweden ($N = 238$), Tunisia ($N = 228$), Turkey ($N = 320$), United Kingdom ($N = 357$), United States ($N = 254$), Venezuela ($N = 188$). We used cultural distance from the United States as a

proxy for the WEIRDness of each country²⁴. These values were available for 18 out of the 23 countries (excluding the US) included in the research (see Table 2 and Table S2)ⁱ.

Table 1
Overview of hypotheses

Main hypothesis		Country-level differences
Science skepticism is heterogeneous		-
Specific hypotheses		
<i>Outcome variable</i>	<i>Predictor(s)</i>	
Climate change skepticism	H1: Political conservatism ^{1,2,10}	H1a: Stronger effect in USA than in other countries ¹⁰
Vaccine skepticism	H2: Spirituality and religious orthodoxy ¹⁻²	H2a: Stronger effect of spirituality in WEIRD countries than in non-WEIRD countries ¹⁻²
	H3: Scientific literacy ¹⁻²	H2b: Stronger effect of orthodoxy in non-WEIRD countries than in WEIRD countries ¹⁻²
GM skepticism	H4: Scientific literacy ^{1,2,12}	-
Evolution skepticism	H5: Religious orthodoxy ^{2,6}	-
Faith in science	H6: Spirituality and religious orthodoxy ¹⁻²	H6a: Stronger effect of spirituality in WEIRD countries than in non-WEIRD countries ¹⁻²
		H6b: Stronger effect of orthodoxy in non-WEIRD countries than in WEIRD countries ¹⁻²

Method

Recruitment of participants. After obtaining approval for the study protocol by the Psychology Research Institute Ethics Committee at the first author's institution (#2018-SP-8701), participants from community samples in 20 countries were recruited via *Kieskompas Opinion Research* (www.kieskompas.nl). The selection strategy included steps to optimize distribution in

ⁱ Interestingly, cultural distance to US maps relatively well onto overall levels of scientific activity present in a nation²³, operationalized by the size of a country's R&D workforce per 1,000,000 residents (in 2012). Exceptions were Sweden (comparatively large cultural distance from USA, relatively large size of R&D workforce), Mexico and Brazil (comparatively small cultural distance from USA, relatively small size of R&D workforce)²³. See Table S2 for the cultural distance and R&D values.

terms of the following demographics: age, gender, educational level, region. Participants from four additional countries were recruited via internet (e.g., email lists, social media; Brazil), research assistants (China and Romania), and Prolific Academic (UK). Our aim was to select at least 250 participants per country²². We managed to collect >95% complete responses from 6904 individuals in 24 countries. Our only predetermined exclusion criterion was an attention check, which read “We would like to make sure that you are paying attention to the wording of the questions. Please fill in the number that corresponds to “somewhat disagree”. 905 individuals (9.4%) failed the check and were excluded. An additional 23 participants were deleted because of a programming error, and 3 participants were deleted for indicating being younger than 18 years. This left us with a final sample of 5973 responses, with an average sample size of 249 per country, ranging from 169 (China) to 357 (UK). Their mean age was 40.9 years ($SD = 13.4$). Gender distribution was 65.6% male and 34.4% female. An overview of demographics can be found in Table S2.

Materials. The study consisted of the following measures. Unless otherwise reported, all items described below were scored on scales ranging from 1 (*strongly disagree*) to 7 (*strongly agree*). Note that we did not expect all predictor variables to have an effect on the outcome variables; some were included primarily as controls, based on previous research. Upon completion of the study, participants were thanked for participation. The complete study materials can be found in Supplement 2.

Outcome variables

Domain-specific science skepticism about climate change, vaccination, genetic modification (GM), and evolution was assessed with measures commonly used in previous work^{1,2,13} ii: “Human CO2 emissions cause climate change”; “Vaccinations cause autism”; “Genetic modification of foods is a safe and reliable technology”; “Human beings, as we know them today, developed from earlier species of animals”. All items except for the vaccination item were reverse-scored so that higher scores indicate more skepticism. General faith in science was measured with a 5-item scale^{1,2,14,15}. An example item is “Science is the most

ⁱⁱ Because of length constraints we used single item measures; these are well-validated and have been shown to produce similar results as multi-item measures^{1,2}.

efficient means of attaining truth” ($\alpha = .84$); full list of items can be found in Supplement 2. In line with previous research^{1,2}, faith in science was held constant when predicting domain-specific skepticism and willingness to support science (see Table 3). Willingness to support science was measured with the following item: “According to you, how much money should the government spend on science?”.^{1,2}

Predictor variables

Political conservatism. Participants were asked to indicate how politically conservative they view themselves on a 10-point scale that ranged from 1 (*very liberal*) to 10 (*very conservative*)ⁱⁱⁱ.

Religiosity. Participants indicated if they considered themselves to be religious (yes or no), and to indicate their religious affiliation^{iv}.

Religious orthodoxy. Religious orthodoxy was measured with two items ($r = .66$) taken from the orthodoxy subscale of the post-critical belief scale^{1,2,17}: “Religion is the one thing that gives meaning to life in all its aspects” and “God has been defined for once and for all and therefore is immutable”.

Spirituality. Participants were asked to indicate whether they considered themselves to be spiritual, using two items ($r = .78$) taken from previous research^{2,18}. Note that this measure was not included for the Chinese sample^v.

Scientific literacy. An 8-item test measuring science literacy was presented. Participants could score anywhere between 0 and 8 points. An example item is “Electrons are smaller than atoms”^{1,19,20}.

ⁱⁱⁱ Additionally, a second political orientation measure was included in the study, which asked participants where they would place themselves on a scale ranging from 1 (*very left-wing*) to 10 (*very right-wing*). Note that for the current purposes we were particularly interested in political conservatism as a predictor and the second measure was not included in the analyses (in line with previous research on science skepticism^{1,2,6,10}).

^{iv} Participants also indicated their belief in God/higher power on a 10-point scale ranging from 1 (*not at all*) to 10 (*very much*). In line with previous research^{1,2}, religious affiliation and belief in God/higher power were not included in the analyses (both in order to keep the amount of predictors limited and because these have been shown to not contribute variance over and beyond religiosity and religious orthodoxy). we included religiosity and orthodoxy as predictors^{1,2}.

^v Chinese participants were instead presented with a measure of materialism, being asked to indicate to what extent they, and others, consider themselves to be ‘materialist’. Materialism scores did not have any effects on the outcome variables, except for a small additional effect on GM skepticism.

Moral purity concerns. Participants completed the moral purity subscale of the moral judgments section of the Moral Foundations Questionnaire^{1,2,16}, which consists of three items (e.g., “I would call some acts wrong on the grounds that they are unnatural”; $\alpha = .70$). No other moral foundations were measured.

Perceived corruption of science. In line with previous research^{1,2}, two statements were presented in which participants indicated to what extent they perceive science to be corrupted by governmental and corporate interference, respectively. These were included as two separate predictors in the analyses reported below²¹.

Demographics

Participants were asked to indicate their age, gender, nationality, country of residence, years of formal education and scientific training, and subjective SES. Table S2 provides an overview of demographics.

Results

Our main goal was to test predictors of general faith in science and willingness to support science, as well as skepticism about four specific scientific domains: climate change, vaccination, GM, and evolution. To this end we conducted multilevel regression analyses for each outcome variable to examine the unique contribution of each predictor, while adjusting for country-level variation. We found no evidence for multicollinearity in the analyses (all Variance Inflation Factors < 2.1). Below, we report multilevel models for the various outcome variables, and then report the strength of the hypothesized effects per country.

Descriptives. Table 2 displays means and standard deviations for each dependent variable across the 24 tested countries. Figure 1 presents a visual overview of science skepticism across countries. Both can be used to acquire a quick overview of how the various countries differ in skepticism, thus illustrating the observed similarities and differences across domains and countries.

Science skepticism across 24 countries

Science skepticism across 24 countries

Table 2

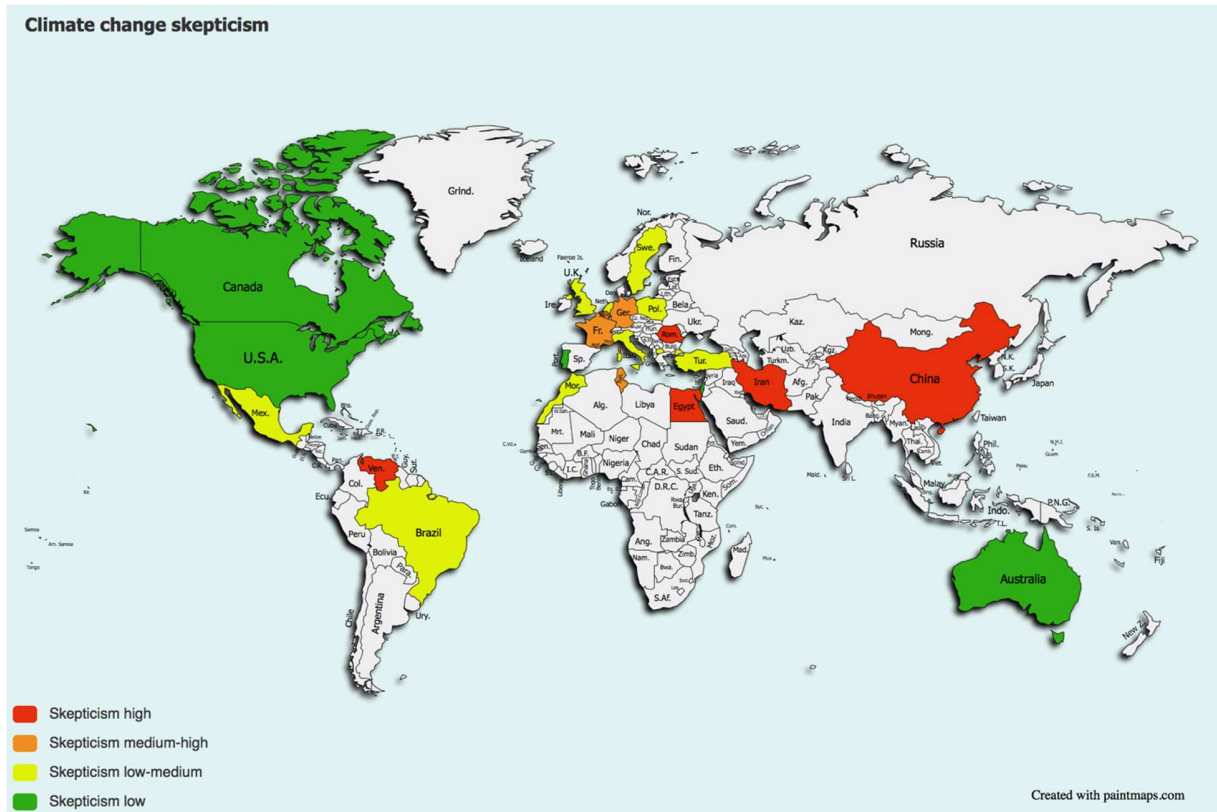
Means and standard deviations of science skepticism, faith in science, and science support across countries

Climate change skepticism			Vaccine skepticism			GM skepticism			Evolution skepticism			Faith in science			Science support			CF _{ST} US	
Country	M	SD	Country	M	SD	Country	M	SD	Country	M	SD	Country	M	SD	Country	M	SD		
Total	2.45	1.77	Total	1.86	1.25	Total	4.57	1.75	Total	2.74	1.94	Total	4.60	1.47	Total	8.47	1.65		
Iran	3.50	2.00	Egypt	2.89	1.71	France	5.72	1.45	Egypt	5.77	2.15	Venezuela	3.52	1.35	UK	7.27	1.66	Egypt	.234
Venezuela	3.28	2.42	Romania	2.56	1.75	Romania	5.70	1.76	Morocco	5.31	2.49	Romania	4.03	1.43	Belgium	7.66	1.63	Tunisia	.156
Romania	3.26	2.23	Morocco	2.36	1.56	Tunisia	5.45	1.84	Tunisia	4.89	2.61	China	4.17	1.15	Netherlands	7.72	1.63	China	.150
China	3.10	1.80	Israel	2.30	1.62	Morocco	5.41	1.89	Romania	3.96	2.43	Mexico	4.29	1.52	France	7.81	1.77	Iran	.150
Belgium	2.91	1.86	Macedonia	2.28	1.66	Turkey	5.41	1.69	Israel	3.91	2.46	Brazil	4.30	1.46	Iran	7.85	1.91	Morocco	.149
Tunisia	2.71	2.16	Turkey	2.26	1.45	Venezuela	5.02	1.67	Venezuela	3.37	2.41	Egypt	4.34	1.34	Romania	7.86	2.10	Turkey	.120
Germany	2.61	1.59	Tunisia	2.20	1.60	Egypt	4.98	1.97	Mexico	2.93	2.36	Tunisia	4.34	1.48	Canada	7.97	1.93	Sweden	.115
UK	2.54	1.60	France	2.09	1.44	Macedonia	4.89	1.92	Turkey	2.85	2.43	Iran	4.35	1.62	Germany	7.97	1.84	Romania	.103
Poland	2.44	1.73	UK	2.08	1.24	Germany	4.88	1.63	Macedonia	2.79	2.29	Morocco	4.38	1.56	Sweden	7.98	1.88	Germany	.080
Italy	2.42	1.74	China	1.96	1.27	Portugal	4.83	1.66	Brazil	2.69	2.22	France	4.42	1.41	USA	7.98	2.08	France	.079
Mexico	2.42	1.95	Iran	1.85	1.25	China	4.69	1.73	Poland	2.44	2.12	UK	4.58	1.47	Portugal	8.42	1.66	Netherl.	.079
Morocco	2.41	2.04	Belgium	1.83	1.23	Mexico	4.58	1.96	Iran	2.42	2.06	Netherlands	4.61	1.49	Brazil	8.49	1.88	Mexico	.077
Netherlands	2.32	1.63	Mexico	1.75	1.56	Israel	4.52	1.91	China	2.17	1.48	Germany	4.63	1.63	China	8.49	1.71	Poland	.076
France	2.30	1.65	Poland	1.73	1.34	Poland	4.46	1.82	UK	2.16	1.59	Israel	4.64	1.49	Poland	8.54	1.88	Brazil	.072
Turkey	2.28	1.79	Netherlands	1.70	1.19	Brazil	4.30	1.72	France	2.13	1.67	USA	4.72	1.56	Australia	8.62	1.47	Italy	.061
Sweden	2.26	1.72	Venezuela	1.69	1.16	UK	4.24	1.56	Netherlands	2.05	1.75	Belgium	4.76	1.51	Venezuela	8.65	1.72	UK	.046
Macedonia	2.24	1.62	Sweden	1.52	1.00	Italy	4.19	1.77	Belgium	2.01	1.60	Canada	4.83	1.41	Italy	9.02	1.25	Australia	.035
Brazil	2.23	1.68	Germany	1.48	0.95	Sweden	4.17	1.81	Portugal	1.94	1.68	Portugal	4.86	1.50	Mexico	9.04	1.56	Canada	.026
Canada	2.06	1.72	USA	1.46	1.05	Belgium	4.13	1.69	Germany	1.92	1.67	Poland	4.90	1.53	Egypt	9.20	1.54	USA	---
Egypt	2.06	1.65	Portugal	1.41	0.87	Iran	3.93	1.69	Canada	1.69	1.53	Australia	4.97	1.35	Tunisia	9.22	1.46	Belgium	n/a
Israel	2.06	1.59	Brazil	1.33	0.76	Netherlands	3.78	1.71	USA	1.69	1.59	Sweden	5.00	1.57	Macedonia	9.23	1.44	Israel	n/a
USA	1.91	1.67	Italy	1.33	0.78	Australia	3.57	1.58	Italy	1.62	1.39	Italy	5.11	1.41	Morocco	9.27	1.41	Maced.	n/a
Portugal	1.70	1.45	Australia	1.31	0.82	USA	3.48	1.69	Sweden	1.62	1.36	Macedonia	5.12	1.52	Israel	9.29	1.23	Portugal	n/a
Australia	1.67	1.24	Canada	1.27	0.76	Canada	3.38	1.79	Australia	1.50	1.26	Turkey	5.41	1.49	Turkey	9.65	1.05	Venezuela	n/a

Note. All scores range from 1-7, except science support (1-10). Science skepticism scores are presented in descending order from high to low. Faith in science and Science support scores are presented in ascending order from low to high. Dotted lines indicate cut-off based on mean totals, so that the countries above the line are more skeptical (and indicate lower faith in science and science support) than the total average. CF_{ST} US = Cultural distance to the United States (from Muthukrishna et al., 2020, Table 1.), ranked by distance: higher values indicate more distance.

Science skepticism across 24 countries

Figure 1. Science skepticism and faith in science across countries. [PLEASE INSERT [Worldmaps.ppsx](#) BELOW]



Note. Maps created on paintmaps.com. Color coding based on <25% mean scores (green); 25%-50% mean scores (yellow); 50%-75% mean scores (orange), >75% mean scores (red).

Multilevel models

For each dependent variable, we fit an empty multilevel model with country as the cluster variable and the same set of group-mean-centered predictor variables (measured at the individual level). This allowed us to test whether there was significant variation in each dependent variable across countries that should be accounted for. In each case, the intra-class correlations (ICCs) and country-level variance estimates indicated that multilevel modelling was necessary and justified (see Table S1). We therefore present all estimates for within-level

coefficients after adjusting for between-level variation in each dependent variable. Table 3 displays the results of these analyses across countries. Note that China was excluded from the multilevel analyses because one of the predictor variables (spirituality) was not included in the study conducted in China.

In addition to the multilevel models, we also (a) zoom in at the hypothesized effects for each of the 24 countries (presented in Figures 2-6)^{vi}, and (b) present the cross-level interaction analyses that test differences between WEIRD and non-WEIRD countries (using cultural distance from the US as a continuous proxy of WEIRDness²⁴).

Tests of hypothesized effects

Climate change skepticism. As shown in Table 3, results supported the prediction that political conservatism would predict climate change skepticism (H1), ($t = 4.58, p < .001$). Figure 2 shows that also as predicted, this effect was arithmetically the strongest in the USA (and Canada), supporting H1a.

Vaccine skepticism. As shown in Table 3, our main hypotheses for vaccine skepticism (H2) received mixed support: it was predicted by spirituality, $t = 4.61, p < .001$, but not religious orthodoxy, $t = 1.51, p = .13$. The further hypothesis (H2a) that the relationship between spirituality and vaccine skepticism would be stronger in WEIRD countries was not supported: the predicted cross-level interaction of spirituality and cultural distance from the US was non-significant, $b = .390, se = .242, p = .108$. Similarly, the hypothesis (H2b) that the relationship between religious orthodoxy and vaccine skepticism would be stronger in WEIRD countries did not receive support, $b = .174, se = .286, p = .543$. Consistent with these nonsignificant cross-level interactions, predicted associations for each country are presented in Figures 3a (spirituality) and 3b (religious orthodoxy), and reveal no consistent distinction between WEIRD

^{vi} Note that all effect sizes depicted in Figures 3-7 were calculated while controlling for all other predictors in the regression analyses. These effect sizes were rounded to 2 decimal places, which might result in very small deviations in overall RE model estimates displayed in the forest plots as compared to the estimates reported in Table 3.

and non-WEIRD nations. Finally, the hypothesis that vaccine skepticism would be negatively predicted by scientific literacy (H3) was supported, $t = -5.96, p < .001$.

GM skepticism. Our main prediction that scientific literacy would predict GM skepticism (H4) was supported. As displayed in Table 3, scientific literacy was a significant negative predictor of skepticism, $t = -8.12, p < .001$. Figure 4 presents the strength of the predicted relationships per country, which was significant in 17 of the included countries^{vii}.

Evolution skepticism. As can be seen in Table 3, H5—religious orthodoxy predicts evolution skepticism—was supported, $t = 8.66, p < .001$. Figure 5 shows the strength of the relationship between religious orthodoxy and evolution skepticism per country, which was significant in almost all (20) countries.

Faith in science. As shown in Table 3, the prediction (H6) that faith in science would be negatively predicted by spirituality, $t = -13.90, p < .001$, and religious orthodoxy, $t = -7.59, p < .001$, received clear support. Moreover, cross-level interaction analyses supported the hypothesis (H6a) that the negative relation between spirituality and faith in science would be stronger in WEIRD countries (slope: $b = -.251, se = .013, p < .001$), than in non-WEIRD countries (slope: $b = -.187, se = .029, p < .001$); the interaction effect between spirituality and cultural distance from the US was significant, $b = .586, se = .280, p = .036$. As shown in Figure 6a, the negative relation between spirituality and faith in science was significant in 20 countries; all except Egypt, Morocco, and Venezuela^{viii}. In stark contrast to these results, significant effects of

^{vii} As can be gleaned from Figure 4, the effect sizes are quite consistent with a few countries that stand out. Israel stands out by a positive association so that more scientific literacy leads to more GM skepticism, which suggests a polarization effect which has previously been observed for climate change skepticism⁶. The regression results showed that none of the additional variables contributed to GM skepticism in the Israeli sample, except for a very small effect of religiosity ($t = -2.07, p = .04$). In the French and Romanian samples, no relation with scientific literacy was observed; interestingly these are also the two countries with the highest levels of GM skepticism. Additional analyses show that in France the regression model performed poorly; none of the included variables contributes significantly to GM skepticism. In Romania, the regression model performed poorly as well with age being the only significant predictor, $t = 4.13, p < .001$.

^{viii} Note that spirituality was not measured in China. In Egypt, the regression model performed well (25% explained variance), with age, religious orthodoxy, and perceived corporate corruption being significant contributors to low faith in science. In Morocco, scientific literacy and perceived corporate corruption were significant contributors in a regression model that explained 17% variance. In Venezuela, the model performed poorly (3.5% variance explained), with religious orthodoxy as the only predictor that approached significance ($t = -.19, p = .058$).

Science skepticism across 24 countries

religious orthodoxy were observed in 9 countries (see Figure 6b). Indeed, the prediction that religious orthodoxy would have a stronger effect in non-WEIRD nations (H6b) was not supported: the cross-level interaction was not significant, $b = .014$, $se = .121$, $p = .908$.

Table 3

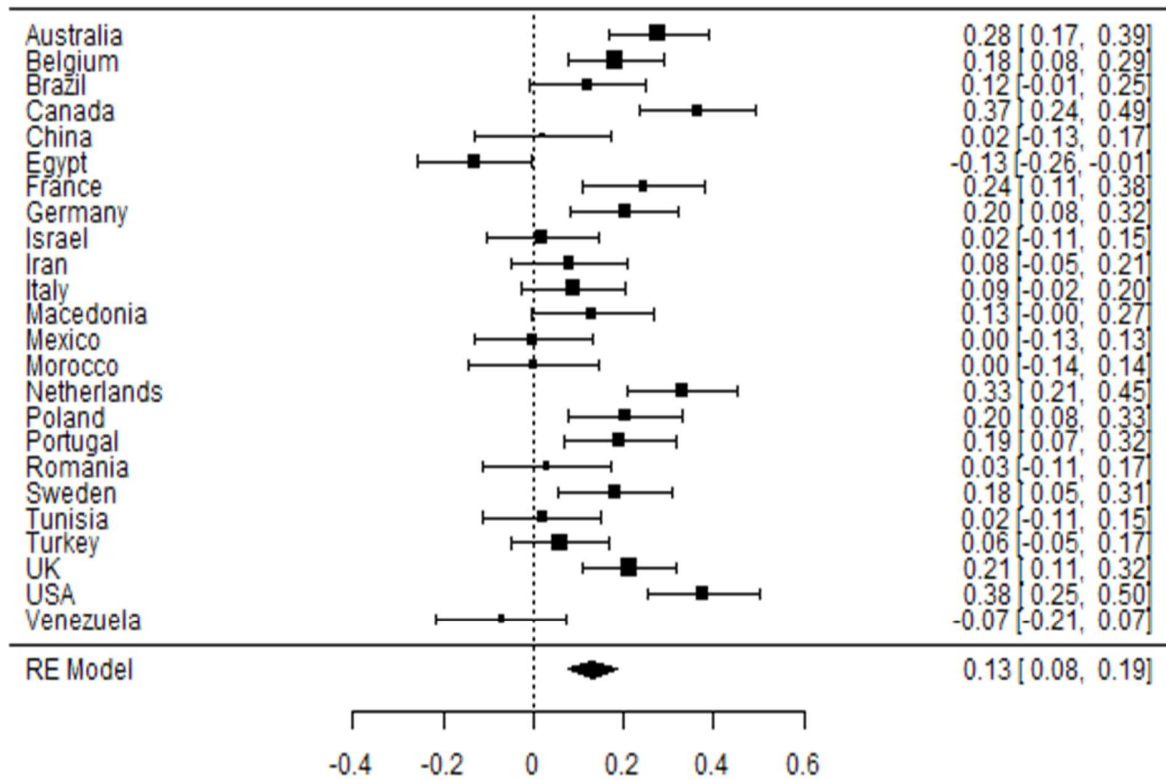
Within-level effects for science skepticism, faith in science, and science support.

	Climate skepticism	Vaccine skepticism	GM skepticism	Evolution skepticism	Faith in science	Science support
	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)
Within level						
Age	.006 (.002)*	.003 (.002)	.010 (.003)**	.003 (.002)	.003 (.002)	.005 (.002)*
Gender	.060 (.066)	-.061 (.040)	.340 (.049)**	.100 (.062)	-.227 (.027)**	.065 (.046)
Moral purity	-.005 (.025)	.084 (.019)**	.167 (.029)**	.169 (.025)**	-.097 (.027)**	-.022 (.029)
Political conservatism	.139 (.030)**	.046 (.013)**	-.041 (.016)	.060 (.014)**	-.054 (.015)**	-.054 (.026)
Spirituality	-.011 (.017)	.066 (.014)**	.043 (.017)	-.028 (.017)	-.232 (.017)**	.031 (.014)
Religiosity [@]	-.004 (.086)	.093 (.050)	.103 (.072)	-.375 (.097)**	.458 (.059)**	-.143 (.071)
Religious orthodoxy	.031 (.027)	.023 (.015)	.049 (.025)	.356 (.041)**	-.136 (.018)**	-.050 (.024)
Science literacy	-.044 (.025)	-.111 (.019)**	-.203 (.025)**	-.140 (.024)**	.061 (.024)^	.056 (.019)*
Faith in science	-.139 (.018)**	-.095 (.013)**	-.226 (.025)**	-.259 (.021)**	-	.365 (.029)**
Gov.corruption	.098 (.026)**	.038 (.012)*	-.014 (.017)	.001 (.014)	.043 (.011)**	-.047 (.030)
Corp.corruption	-.084 (.023)**	.045 (.015)*	.132 (.024)**	-.001 (.020)	-.083 (.009)**	.084 (.024)**

Note. * $p < .01$; ** $p < .001$. China not included. Estimates are unstandardized. [@]Note that religiosity was scored as 1=yes; 2=no, and so a negative estimate indicates a positive relation with religiosity.

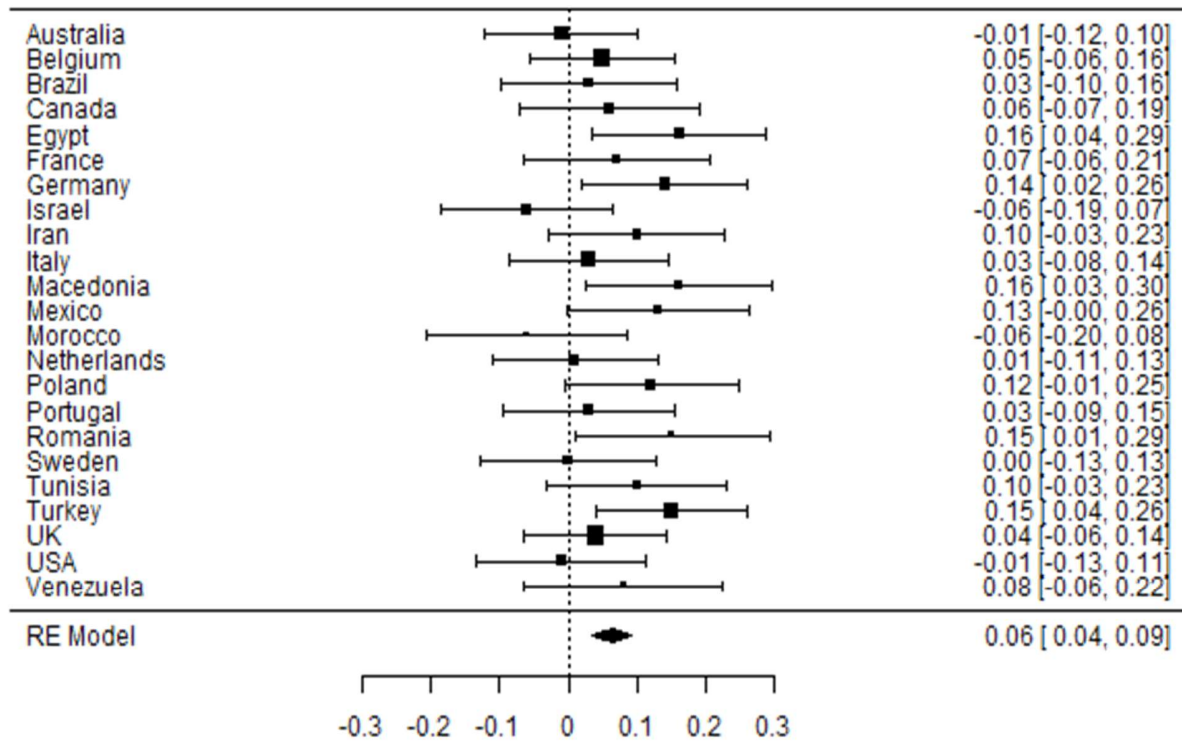
Science skepticism across 24 countries

Figure 2. Relationship between political conservatism and climate change skepticism across 24 countries (controlling for age, gender, faith in science, and for the other predictors).



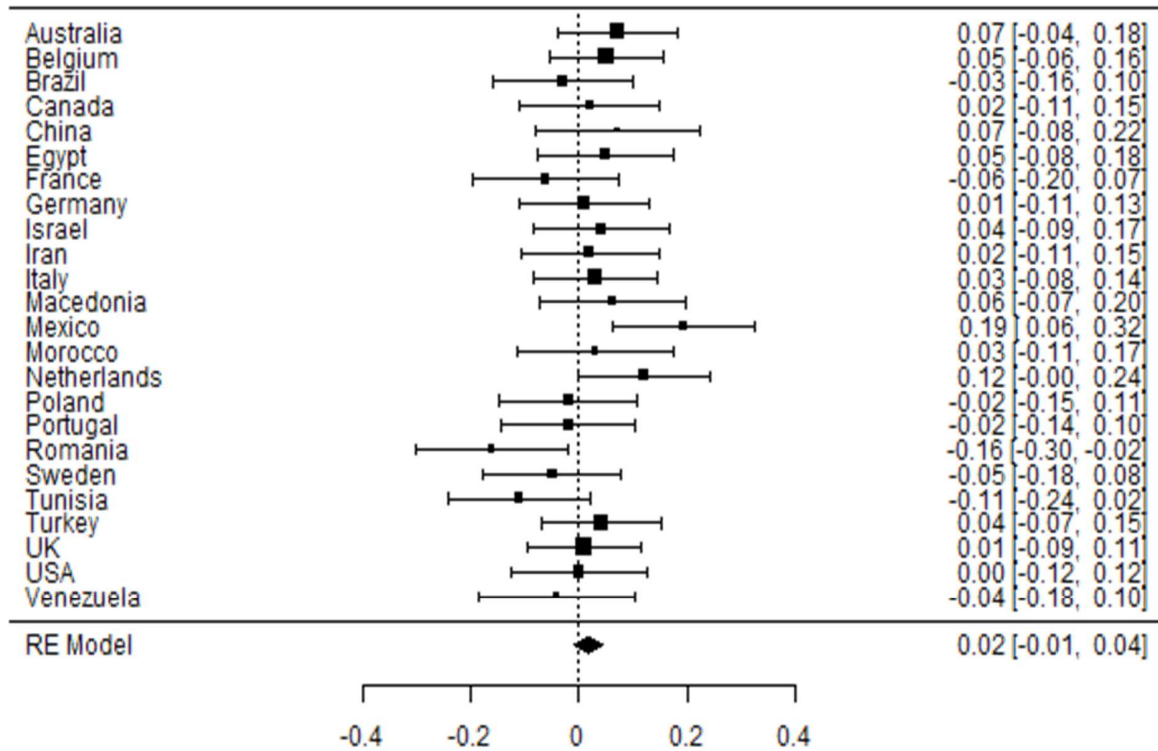
Science skepticism across 24 countries

Figure 3a. Relationship between spirituality and vaccine skepticism across 23 countries (controlling for age, gender, faith in science, and for the other predictors).



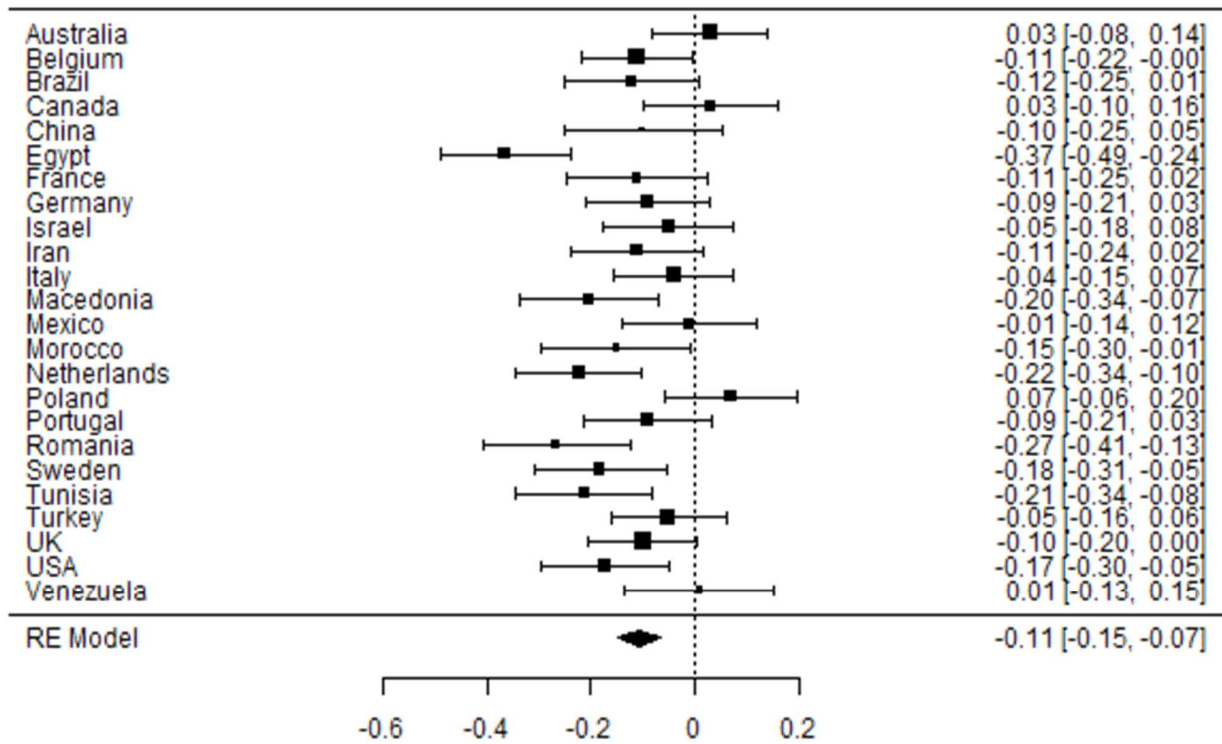
Science skepticism across 24 countries

Figure 3b. Relationship between religious orthodoxy and vaccine skepticism across 24 countries (controlling for age, gender, faith in science, and for the other predictors)



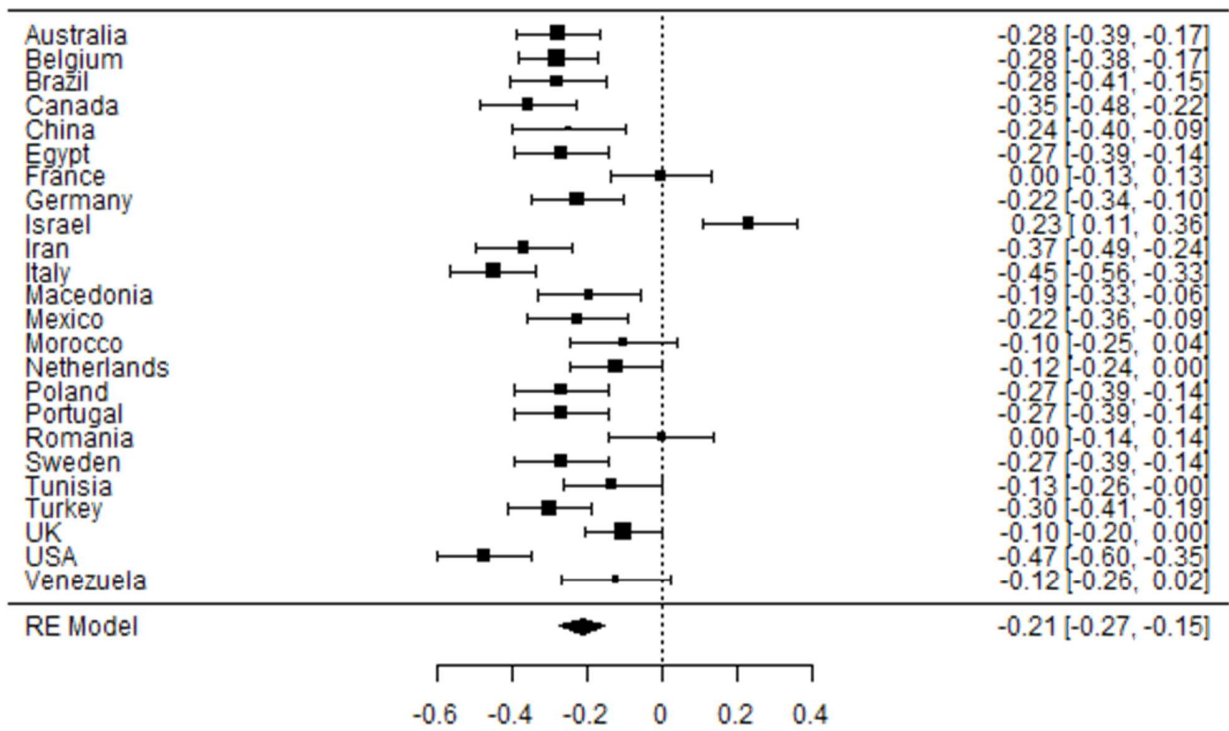
Science skepticism across 24 countries

Figure 3c. Relationship between scientific literacy and vaccine skepticism across 24 countries (controlling for age, gender, faith in science, and for the other predictors).



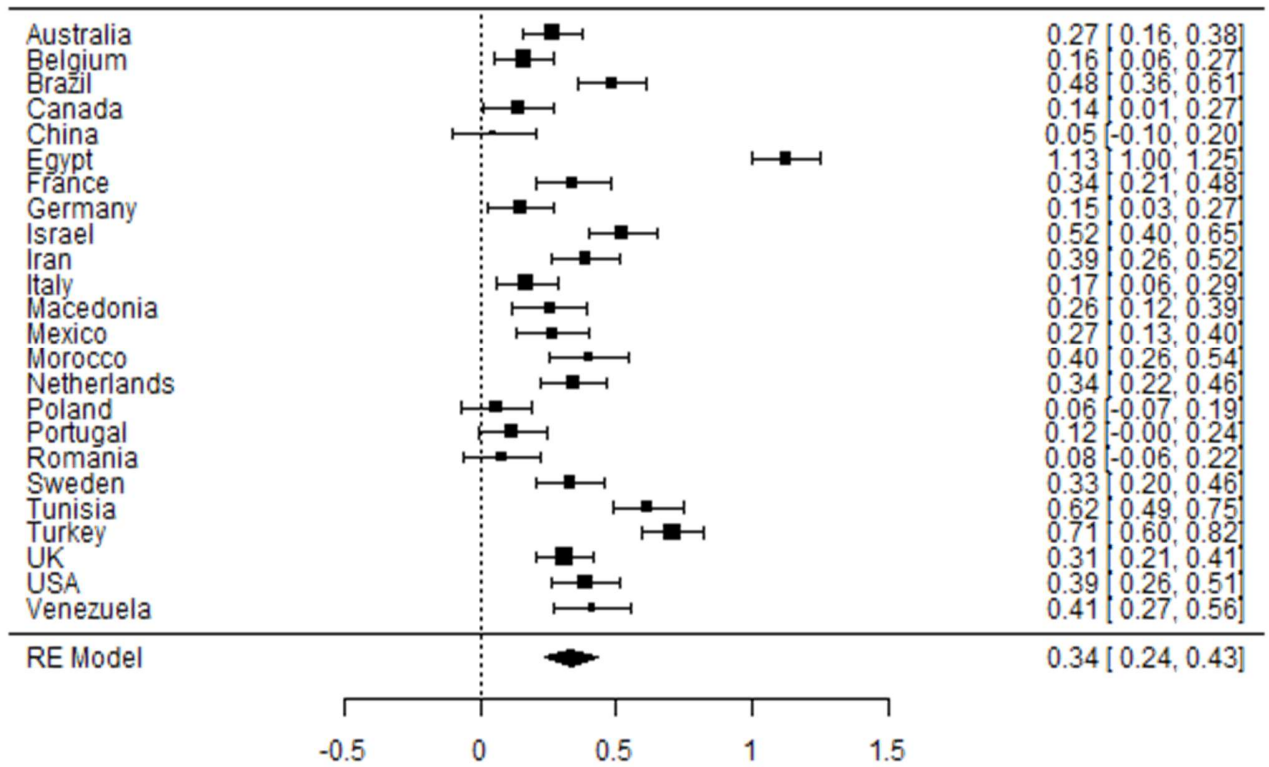
Science skepticism across 24 countries

Figure 4. Relationship between scientific literacy and GM skepticism across 24 countries (controlling for age, gender, faith in science, and for the other predictors).



Science skepticism across 24 countries

Figure 5. Relationship between religious orthodoxy and evolution skepticism across 24 countries (controlling for age, gender, faith in science, and for the other predictors).



Science skepticism across 24 countries

Figure 6a. Relationship between spirituality and faith in science across 23 countries (controlling for age, gender, and for the other predictors)

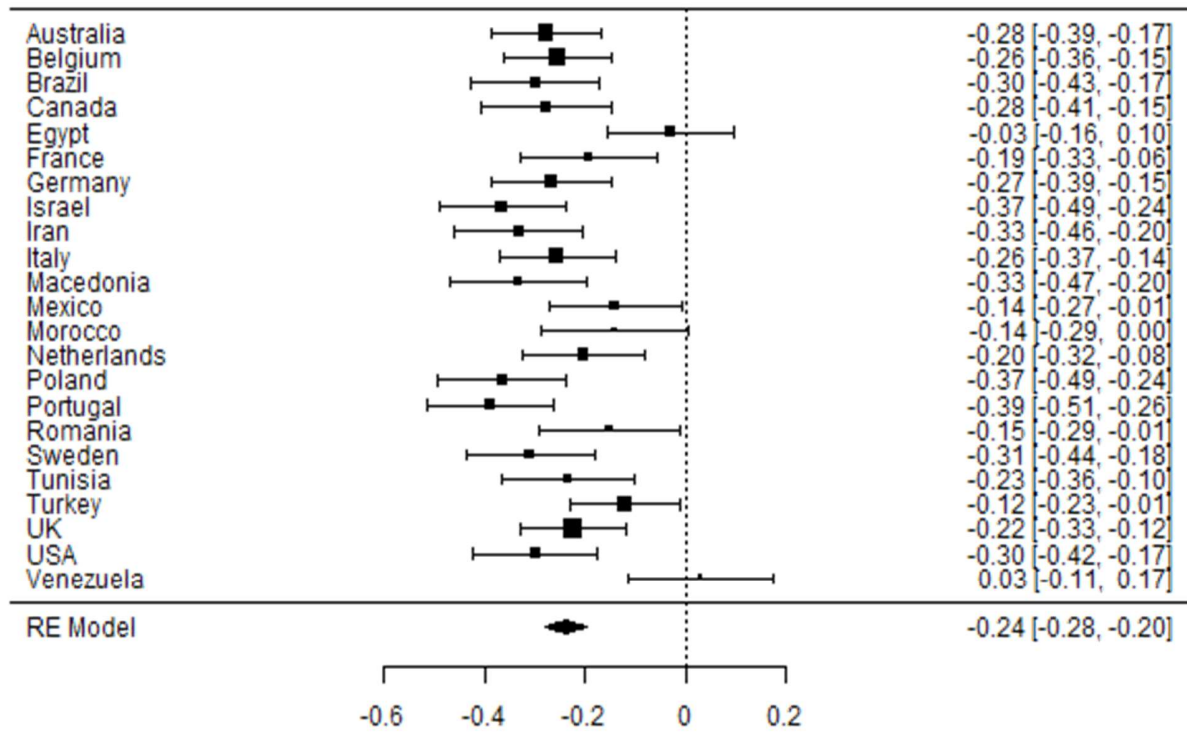
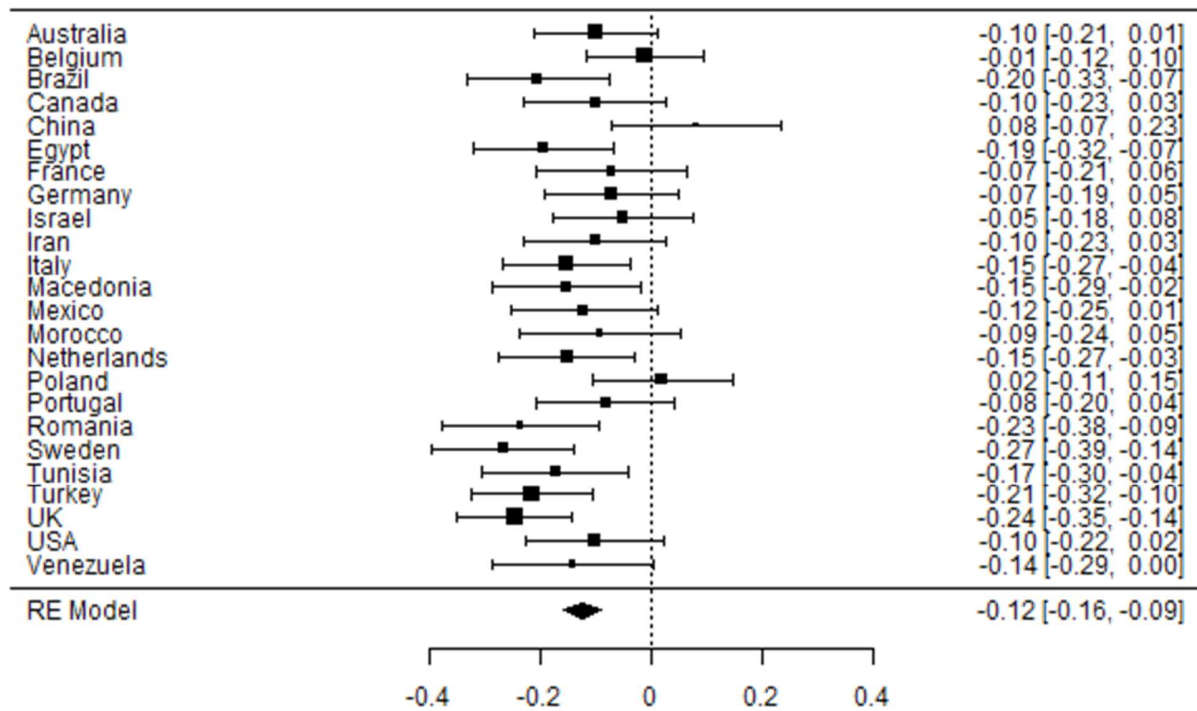


Figure 6b. Relationship between religious orthodoxy and faith in science across 24 countries (controlling for age, gender, and for the other predictors).



Other notable results

Science support. As displayed in Table 3, willingness to support science was best predicted by faith in science ($t = 12.65, p < .001$), which corroborates previous work.¹⁻²

Other contributors to science skepticism. As can be seen in Table 3, some additional relations were observed. Most notably and consistently, faith in science—which was included as a predictor^{ix} in the analyses predicting domain-specific science skepticism—contributed

^{ix} Since controlling for faith in science might be overly conservative, we reran all analyses on domain-specific skepticism without controlling for faith in science. This did not meaningfully change the outcomes of any of the multilevel models, nor did it affect the reported cross-level interaction effects for vaccine skepticism.

substantially to the explained variance for all four domains of skepticism, in line with previous research¹⁻².

Discussion

The extent to which science skepticism varies in degree and in kind around the world is not well understood. Up to now, a systematic cross-national investigation of the relative impact of various potential predictors of science skepticism across domains was lacking. This lacuna has obstructed efforts to understand and remedy the rejection of science - a phenomenon that is causing catastrophic health, economic, and environmental harms^{4,25}. The current paper reports the results of the first large-scale effort to address this lacuna. In so doing, this work provides clear support for the heterogeneity of science skepticism, both in degree (levels of skepticism vary across domains but also across countries) and in kind (different predictors drive science skepticism in different domains). As formalized in our main hypotheses (H1 to H6), we expected different predictors to drive skepticism in different domains, within and across nations. All main hypotheses were supported, except for H2 (we did not find evidence that religious orthodoxy uniquely contributes to vaccine skepticism). We had also expected some heterogeneity to manifest *between* nations, such that WEIRD and non-WEIRD nations would show systematic variation in patterns of science skepticism. These predictions were formalized in the country-level hypotheses (H1a, H2a-b, and H6a-b). It was indeed found that the impact of political conservatism on climate change skepticism was strongest in the USA (H1a) but note that it was equally strong in Canada (followed by other WEIRD nations; Australia and The Netherlands). Evidence for the hypotheses that vaccine skepticism and low faith in science would be best predicted by spirituality in WEIRD nations (H2a-H6a) and by orthodoxy in non-WEIRD nations (H2b-H6a) was found for faith in science but not for vaccine skepticism. Taken together, the results show that, of the various beliefs and ideologies examined as predictors of science skepticism, spirituality is among the most important.

Indeed, confirming previous results obtained in the Netherlands²—and providing strong support for Hypothesis 6—the current data speak to the crucial role of spirituality in fostering

low faith in science, more generally, beyond its domain-specific effects on vaccine skepticism. This indicates that the negative impact of spirituality on faith in science represents a cross-national phenomenon that is more generalizable than might be expected based on the large variety²⁴ of countries included here. A possible explanation for the robustness of this effect may lie in the inherent irreconcilability of the *intuitive epistemology* of a spiritual belief system with science². (If so, then we might look at a potentially much larger problem that extends beyond spirituality and applies more generally to “post-truth” society, in which truth and perceptions of reality may be based on feelings rather than facts^{28,29}). However, these results do not mean that traditional religiosity as a predictor of science skepticism^{1,5,11} has now become irrelevant: Not only did religious orthodoxy significantly contribute to low faith in science, it was also found to be a very consistent cross-national predictor of evolution skepticism (but not of other forms of science skepticism included in the study).

Research has started to challenge the widespread notion that science skepticism primarily results from a lack of knowledge^x. In the current work, scientific literacy was the main driver of science skepticism *only* in the domain of GM. This corroborates previous research and observations that suggest that merely addressing information deficits to combat science skepticism is in most cases not sufficient^{2,5,12}.

The cross-national approach of the current work is important because it provides support for the emerging theoretical understanding of what causes skepticism across different domains of science^{2,5,9-12}, and does so by including various countries that have been virtually absent from the psychological science database^{8,24,30}. The present results demonstrate that while predictors of science skepticism to some extent vary in predictable ways between countries, many of the hypothesized effects were observed across many of the included countries. *Levels* of skepticism showed more regional variation. This heterogeneity of science skepticism in degree is illustrated in Table 2 and Figure 1, with some countries standing out as being especially high or low on skepticism. For example, in Egypt, Romania, and Venezuela, science skepticism is much stronger than in Australia or Canada. Additionally, remarkable

^x See a recent review article that details some of that work⁵

differences in science skepticism were observed within countries, depending on the domain (e.g., GM skepticism versus skepticism in other domains in France, general faith in science versus domain-specific skepticism in Turkey).

One obvious and important limitation to the current work concerns the limited nature of the measures used. Many of the key measures employed were self-report single-item (i.e., most outcome variables) or two-item indices (i.e., most of the predictor variables). The brevity of the materials was necessary in order to keep study length constrained. Thus, the construct validity and (cross-cultural) reliability of these measures are necessarily limited, and we hope that future research will replicate and extend (some of) these results with better measures and extensive equivalence testing. That being said, the current measures have been used frequently in previous work; the single-item outcome measures have been shown to produce similar results as multi-item variants¹⁻², and the spirituality and religious orthodoxy indices consist of the items with the highest factor loadings¹⁻².

In conclusion, the present results can support the further development of our understanding of the various causes of science skepticism in different domains and in different cultures and countries, which in turn may help support interventions and communication strategies. Indeed, these results may be particularly informative when the aim is to understand how trust in science and compliance with its recommendations vary across individuals and countries, for example during a global pandemic like Covid-19. To illustrate, let us return to the more general problem of vaccine hesitancy as an example of how skepticism can pose serious risks to public health. The current results suggest that increasing scientific literacy might prove to be a more fruitful approach in some cultural contexts than in others (see Figure 3-c). In contrast, a better understanding of the relation between spiritual beliefs and general science skepticism is likely to be extremely informative regardless of cultural context. Regardless, it is evident that any strategy aimed at combating science skepticism needs to be underpinned by a nuanced theoretical and empirical understanding of its causes, across domains as well as cultural contexts.

References

- 1 Rutjens, B. T., Sutton, R. M., & van der Lee, R. (2018). Not all skepticism is equal: Exploring the ideological antecedents of science acceptance and rejection. *Personality and Social Psychology Bulletin*, *44*(3), 384-405.
- 2 Rutjens, B. T., & van der Lee, R. (2020). Spiritual skepticism? Heterogeneous science skepticism in the Netherlands. *Public Understanding of Science*, *29*, 335-352.
- 3 Higgins, K. (2016). Post-truth: a guide for the perplexed. *Nature*, *540*(7631), 9-9.
- 4 Wellcome Trust (2019), 'Wellcome Global Monitor: How Does The World Feel About Science and Health?', <https://wellcome.ac.uk/reports/wellcome-global-monitor/2018>
- 5 Rutjens, B. T., Heine, S. J., Sutton, R. M., & van Harreveld, F. (2018). Attitudes towards science. *Advances in Experimental Social Psychology*, *57*, 125-165.
- 6 Drummond, C., & Fischhoff, B. (2017). Individuals with greater science literacy and education have more polarized beliefs on controversial science topics. *Proceedings of the National Academy of Sciences*, *114*(36), 9587-9592.
- 7 Henrich, J., Heine, S. J., & Norenzayan, A. (2010). The weirdest people in the world?. *Behavioral and brain sciences*, *33*(2-3), 61-83.
- 8 Hruschka, D. J., Medin, D. L., Rogoff, B., & Henrich, J. (2018). Pressing questions in the study of psychological and behavioral diversity. *Proceedings of the National Academy of Sciences*, *115*(45), 11366-11368.
- 9 Hornsey, M. J., Harris, E. A., & Fielding, K. S. (2018). The psychological roots of anti-vaccination attitudes: A 24-nation investigation. *Health Psychology*, *37*, 307-315.
- 10 Hornsey, M. J., Harris, E. A., & Fielding, K. S. (2018). Relationships among conspiratorial beliefs, conservatism and climate scepticism across nations. *Nature Climate Change*, *8*, 614-620.
- 11 McPhetres, J., & Zuckerman, M. (2018). Religiosity predicts negative attitudes towards science and lower levels of science literacy. *PloS one*, *13*(11), e0207125.
- 12 McPhetres, J., Rutjens, B.T., Weinstein, N., & Brisson, J.A. (2019). Modifying attitudes about modified foods: increased knowledge leads to more positive attitudes. *Journal of Environmental Psychology*, *64*, 21-29.

13 Lewandowsky, S., Gignac, G. E., & Oberauer, K. (2013). The role of conspiracist ideation and worldviews in predicting rejection of science. *PloS one*, 8(10), e75637.

14 Farias, M., Newheiser, A. K., Kahane, G., & de Toledo, Z. (2013). Scientific faith: Belief in science increases in the face of stress and existential anxiety. *Journal of Experimental Social Psychology*, 49(6), 1210-1213.

15 Hayes, B. C., & Tariq, V. N. (2000). Gender differences in scientific knowledge and attitudes toward science: A comparative study of four Anglo-American nations. *Public Understanding of Science*, 9, 433-447.

16 Graham, J., Haidt, J., & Nosek, B. A. (2009). Liberals and conservatives rely on different sets of moral foundations. *Journal of Personality and Social Psychology*, 96(5), 1029.

17 Fontaine, J. R., Duriez, B., Luyten, P., & Hutsebaut, D. (2003). The internal structure of the Post-Critical Belief Scale. *Personality and Individual Differences*, 35, 501-518.

18 Maij, D. L., & van Elk, M. (2018). Getting absorbed in experimentally induced extraordinary experiences: Effects of placebo brain stimulation on agency detection. *Consciousness and Cognition*, 66, 1-16.

19 Hayes, B. C., & Tariq, V. N. (2000). Gender differences in scientific knowledge and attitudes toward science: A comparative study of four Anglo-American nations. *Public Understanding of Science*, 9, 433-447.

20 Kahan DM (2015) Climate-science communication and the measurement problem. *Political Psychology*, 36, 1–43.

21 Pechar, E., Bernauer, T., & Mayer, F. (2018). Beyond political ideology: The impact of attitudes towards government and corporations on trust in science. *Science Communication*, 40(3), 291-31

22 Schönbrodt, F. D., & Perugini, M. (2013). At what sample size do correlations stabilize? *Journal of Research in Personality*, 47, 609-612.

23 World Bank (2019) Researchers in R&D (per million people). Available at: <https://data.worldbank.org/indicator/SP.POP.SCIE.RD.P6>

Science skepticism across 24 countries

24 Muthukrishna, M., Bell, A. V., Henrich, J., Curtin, C. M., Gedranovich, A., McInerney, J., & Thue, B. (2020). Beyond Western, Educated, Industrial, Rich, and Democratic (WEIRD) Psychology: Measuring and Mapping Scales of Cultural and Psychological Distance. *Psychological Science, 31*, 678–701

25 World Health Organization (2019). Ten threats to global health in 2019. Retrieved from: https://www.who.int/emergencies/ten-threats-to-global-health-in-2019?utm_source=Nature+Briefing&utm_campaign=56b34e1370-briefing-dy-20190116&utm_medium=email&utm_term=0_c9dfd39373-56b34e1370-42643803

26 Malik, A. A., McFadden, S. M., Elharake, J., & Omer, S. B. (2020). Determinants of COVID-19 Vaccine Acceptance in the US. *medRxiv*.

27 Cornwall, W. (2020). Just 50% of Americans plan to get a COVID-19 vaccine. Here's how to win over the rest. *Science, 29*, A.

28 Rutjens, B. T., & Brandt, M. J. (2018). Belief systems and the perception of reality: An introduction. In B.T. Rutjens & M.J. Brandt (Eds.). *Belief systems and the perception of reality*. Oxon, UK: Routledge

29 Martel, C., Pennycook, G., & Rand, D. G. (2020). Reliance on emotion promotes belief in fake news. *Cognitive research: principles and implications, 5*(1), 1-20.

30 Apicella, C., Norenzayan, A., & Henrich, J. (2020). Beyond WEIRD: A review of the last decade and a look ahead to the global laboratory of the future. *Evolution and Human Behavior, 41*(5), 319-329.