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Which foreign vaccine should the government purchase in a pandemic? Evidence from a survey experiment in the United States

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ABSTRACT

Background: For many countries confronting a future pandemic, the initial vaccines available will come from abroad. Public hesitancy to receive these foreign vaccines is important, as it may create an incentive for governments to forego procuring them for public use. We investigate the influence of the vaccine's country of origin on public support for government procurement during the early stages of a pandemic and examine whether endorsements from the WHO can mitigate such biases.

Methods: In the summer of 2023, we carried out a survey experiment of 1,110 U.S. residents where we asked respondents to rate their support for vaccine purchasing policies for 20 hypothetical vaccines (13,320 evaluations). We varied the vaccine's country of origin and its endorsement status from the WHO, while also randomizing other vaccine attributes.

Results: Compared to foreign vaccines from countries Americans see favorable (e.g., Germany, the United Kingdom), those originating from less favorable countries (e.g., China, Russia), garnered lower support for government procurement. Our causal mediation analysis indicates that this country-of-origin effect is primarily driven by participants' sentiments toward the vaccine. Surprisingly, WHO endorsement does little to mitigate the effect of the vaccine's country of origin. These findings are consistent across various sample subsets and considerations of vaccine quality.

Conclusion: Our study advances previous work on vaccine country-of-origin effects by assessing its impact on policy preferences for procuring initial vaccines from overseas (as opposed to uptake intentions), identifying a mechanism by which vaccine favoritism occurs, and documenting that neither personal disease susceptibility nor vaccine quality fully mitigates country of origin effects. We conclude by discussing why the study of "vaccine diplomacy" ought to not only include interstate dynamics governing vaccine purchasing and availability but also consider vaccine-producing countries' more general reputations.

1. Introduction

Vaccines play a vital role in controlling the spread of infectious diseases, particularly those made available early in public health emergencies. This is true even if these initial vaccines are not as effective as those developed later on. However, challenges such as lengthy regulatory approval processes and logistics and supply chain issues related to vaccine manufacturing and distribution often hinder their potential. One notable challenge is that for almost the entire world, these initial vaccines will originate from and be produced in foreign countries, which can affect government effort to control disease spread. For context, of the eleven COVID-19 vaccines recommended for public use by the World Health Organization (WHO), six originated wholly or partially from the United States.

The foreign origin of vaccines can be consequential for governments aiming to curb the spread of infectious diseases in two ways. First, recent work has shown strong "country of origin effects" (i.e., preferences for vaccines produced in some countries relative to others) and "home country bias" (i.e., the preference for vaccines developed in one's own country) in individuals' willingness to receive COVID-19 vaccines

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(Barceló et al., 2022; Chiang et al., 2022; Kobayashi et al., 2021; Motta, 2021; Kobayashi et al., 2022; Kreps et al., 2020; Papp and Nkansah, 2023). Consequently, even when these initial vaccines become accessible, foreign origins may evoke hesitancy within the population.

Second, governments may struggle to procure foreign vaccines, not just due to supply chain issues but also because of the lack of public support for their procurement policy. Consider, for example, the Sputnik V vaccine from Russia. Early on in its development, U.S. government officials were wary to purchase orders of Sputnik V, due in part to ethical concerns about non-standard clinical trial testing (Beaumont and Harding, 2020). Relatedly, we suspect it is quite plausible that the U.S. federal government may have anticipated popular backlash to ordering a Russian vaccine, as (according to some public opinion research) over 7 in 10 Americans express unfavorability toward the Russian government (which was involved in both the development and roll out of Sputnik V) (Huang, 2020). In contrast, the early vaccines developed in Germany (by BioNTech, together with a U.S. company) and in the U.K. and Sweden (AstraZenica), all countries seen as highly favorable by the U.S. public, were ultimately purchased by the U.S. government.

This challenge involving governments' decisions to procure foreign vaccines could not be more consequential, as these decisions precede citizens' choices to receive them. Without successful procurement, the public will not even have the option to get vaccinated, regardless of their desire or willingness to do so, assuming exclusive statist vaccine procurement. Our study shifts the focus from vaccine uptake to public support for government procurement of initial foreign vaccines at the onset of a pandemic (for one notable exception, see Sheen et al. (2023)). We focus on whether, and the extent to which, the origin country of initial vaccines influences citizens' attitudes toward procurement policy and, importantly, strategies aimed at mitigating potential biases associated with origin in public support. In this study, we develop and implement a survey experiment aimed at addressing these questions.

For ease of writing, we will refer to the countries of vaccine origin that a foreign population might not feel favorable or actually animosity towards as "unfavorable countries", in contrast to "favorable countries." It is crucial to emphasize that this distinction does not definitionally imply a judgment about how people feel toward a vaccine. This aspect will be a point of our investigation within this project.

Our examination of vaccine origins, perceptions of vaccines, and the support for the government to procure a vaccine consists of four steps. First, we hypothesize that people perceive initial vaccines from unfavorable countries as being of lower quality when compared to those from favorable countries. This divergence in perception is expected to occur even when clinical data regarding effectiveness and side effects are otherwise similar. This hypothesis is strongly suggested by existing evidence that people are more hesitant to accept vaccines produced in certain countries in contrast to those originating from other countries (e.g., Motta, 2021; Kobayashi et al., 2022; Kreps et al., 2020).

Second, we posit that people's subjective assessment of a vaccine serves as the primary mechanism by which they come to approve or disapprove their government's effort to purchase vaccines from foreign countries. If vaccines originating from unfavorable countries tend to be subjectively appraised in more negative terms, we hypothesize that individuals are less likely to support their government's procurement of vaccines produced in unfavorable nations as opposed to favorable ones. In other words, we suspect that the impact of an unfavorable country of origin on policy preferences is substantially mediated by the affect toward the vaccine (for a mediation analysis similar to ours but with different outcome and mediator variables, see Chiang et al. (2022)).

Third, while one might anticipate that concerns about the personal or public health risks of vaccinating (or failing to do so) would lead them to evaluate vaccines primarily based on their clinical merits, past work suggests that country-of-origin effects could potentially disrupt this evaluative process. We propose that a neutral third party could provide such assurances about vaccine quality that supersede the effects of the country of origin, so long as that organization is highly trusted (Sheen et al., 2023). A fitting candidate for this role is the World Health Organization (WHO). Recent globally representative public opinion research suggests that a plurality of people around the world express high levels of trust in the WHO (Wellcome, 2021). Existing evidence indicates that WHO endorsements in public health can lead people to adopt measures (Kreps et al., 2020; Kobayashi et al., 2023; Bayram and Shields, 2021; Determann et al., 2016). Moreover, recent findings from Sheen et al. (2023) also show that WHO endorsement might positively impact the acceptance of vaccines from unfavorable countries, such as Chinese vaccines among Taiwanese people, while potentially dampening the acceptance of already trusted vaccines like American or German vaccines. In our study, we investigate whether WHO endorsement might suppress country-of-origin effects on public support for government vaccine procurement.

Finally, recognizing the importance of rapid and early vaccination during an infectious disease outbreak, it is worth considering that less effective vaccines administered early in a pandemic could actually yield greater public health benefits than waiting for more potent and safer alternatives that might become available later. In a way, the world was "lucky" that COVID-19 vaccines produced early on in the pandemic were deemed both safe *and* highly effective vaccines accessible within a year of its onset. However, looking ahead, we are likely to be in situations where the public needs to be convinced to embrace vaccines with lower efficacy and higher potential for side effects in order to effectively tackle emerging infectious disease threats. With this perspective in mind, we extend our analysis by presenting a comprehensive analysis encompassing all effects, including moderations and mediations, for vaccines of lower quality.

We study all of the above in a survey experiment conducted in the United States in late summer 2023. We designed a hypothetical future flu pandemic, which we modeled after the public health risks attributable to COVID-19, to serve as the context for a series of hypothetical first available vaccines (Brutger et al., 2022; McDonald, 2020). Each vaccine is presented in a tabular manner with information about effectiveness, side effects, practical aspects (number of injections, technology), and whether the WHO endorsed the vaccine. For the country of origin, we rely on Russia and China as unfavorable and the U.K. and Germany as favorable countries in the context of a U.S.-based experiment. Below each vaccine, we pose two questions. First, we ask people to express how warm or cold they feel toward the vaccine, a measurement technique taken from political science. Second, people may state to which extent they support their government in procuring the vaccine and making it available to the public. We expect the former to mediate the effect of the country of origin on the latter, with moderation provided by the WHO endorsement. We then repeat our analyses by restricting our data to vaccines of lower quality.

We find very clear and consistent results. Vaccines from unfavorable countries generate considerably colder feelings from respondents compared to those from favorable countries, and these feelings in turn effect much lower support for the government to pursue the purchase of them. Taken together, we find considerable evidence that the country-of-origin effect in policy support is an indirect effect working through how people feel toward a first-available vaccine.

We argued and hypothesized that WHO approval would serve as a great leveler. While the WHO endorsement of a vaccine boosts feelings for and support for the government to procure a vaccine by about 20-21% of one standard deviation, in line with other effects of WHO guidance (Bayram and Shields, 2021; Kobayashi et al., 2023). However, we observe no evidence of moderation and mediation effects. These results are clearly not consistent with the hypothesized leveling effect of a WHO endorsement.

Further, both the mediation by favorability and the inefficacy of WHO endorsements are remarkably stable for every pair of favorable (Germany, U.K.) and unfavorable (China, Russia) origin, for vaccines of lower quality, for respondents with particular health vulnerability

or susceptibility to persuasion, and allowing our mediating variable—feelings toward the vaccine—to have a non-linear effect.

These results have important public health and health policy implications, which we discuss at the end of paper. In particular, we consider how the politics and diplomatic aspects of vaccine policy need to be of high importance.

2. Methods

We employ a randomized controlled trial (RCT) embedded in a public opinion survey to assess the effects of vaccines' countries of origin on vaccination policy preferences. To do this, we first present survey respondents with a hypothetical influenza pandemic scenario and then ask them to consider a series of hypothetical first-available vaccines, which differ in their clinical features (e.g., efficacy in preventing severe illness, antigen type), country of origin, and whether the WHO endorsed each one. Respondents then express their views on the vaccine and whether they support the federal government purchasing it. A key part of the experiment is causal mediation via feelings toward the vaccine as well as effect moderation by WHO endorsement. The analyses, with a few deviations described in the text, follow our pre-analysis plan (PAP), which we registered in August 2023 and can be accessed via the OSF website (http://bit.ly/3ZCdzt1). Additionally, the experiment was granted IRB approval from the University of South Carolina prior to being conducted.

We chose the United States as the initial location to carry out our experiment with an understanding that our findings hold the potential for broader insights. Existing evidence suggests that Americans are generally receptive to guidance and endorsements from the WHO regarding health policy (Kobayashi et al., 2023) and, more specifically, vaccination (Kreps et al., 2020). Moreover, recent research indicates that findings from survey experiments focusing on the general public's perceptions of foreign countries, international institutions, and trade, when based on U.S. samples like ours, exhibit a high degree of generalizability to various other contexts, including those in developing countries (Bassan-Nygate et al., 2023). This evidence bolsters our confidence in the applicability of our findings to diverse contexts, a point we will revisit in the discussion section.

2.1. Sample

We solicited participants from Prolific, an Oxford University-based online opt-in survey recruitment platform designed to aid researchers in disseminating opportunities to participate in public opinion research. Participants are offered compensation to partake in these surveys. Although comparable to platforms like Amazon's MTurk, Prolific is specifically engineered for academic survey research. Research indicates that Prolific garners a more diverse and higher quality participant pool compared to other digital platforms, such as Amazon's MTurk (Palan and Schitter, 2018; Peer et al., 2017). In September 2023, we recruited 1,110 residents in the United States who performed 13,320 evaluations of vaccines.

Opt-in samples in the U.S. tend to skew younger and more liberal than the target population (Huff and Tingley, 2015; Berinsky et al., 2012). Therefore, we stratified the survey-taking opportunities on Prolific by intersections of age (18-24, 25-34, 35-50, 51-60, 61-100) and party identification (Republican, Democrat, Other/Don't Know), following their frequencies in our target data, the 2022 Cooperative Election Study (CES) (Schaffner et al., 2023).

To reduce remaining imbalances vis-à-vis our target population, we employ entropy balancing for the reweighting of our samples (Hainmueller, 2012). This technique calculates non-zero weights for the survey data so that the means of designated demographic variables align with those of the target dataset, while simultaneously minimizing large weights to reduce dependency on subsequent models. For demographic reweighting, we use age, gender, whether one has not taken any COVID-19 vaccine, and party affiliation indicators for Democrats and Republicans. The reference dataset is again the 2022 CES. We utilize the trimmed-weights method provided by entropy balancing, and all analyses are conducted with the re-weighted data. Fig. A.2 in SI shows how rebalancing leads to minuscule final imbalance vis-à-vis the reference data set.

2.2. Experimental design

We ask respondents to imagine a future, hypothetical scenario of a flu pandemic. While designing this scenario, we deliberately, but without explicitly informing the respondents, based it on the public health consequences similar to those observed during the COVID-19 pandemic. Recent research indicates that hypothetical-based experiments mirror results observed using real-world contexts, especially when examining policy preferences (Brutger et al., 2022; McDonald, 2020). The description of the pandemic's health risks is closely adapted from how the U.S. Centers for Disease Control and Prevention (CDC) and the WHO describe COVID-19. The text states that while a significant portion of those infected will have mild symptoms, there will be individuals who "will become seriously ill and require medical attention and hospitalization." Notably, the text highlights that "[o]lder people and those with underlying medical conditions like cardiovascular disease, diabetes, chronic respiratory disease, or cancer" are identified as particularly vulnerable. The full text is given in Section A in SI.

Following this background information, we tell respondents that the U.S. government would have to decide whether to purchase a particular foreign vaccine and that "a vaccine originating in the United States will not be available for at least another six months." We state that respondents would be shown a series of hypothetical first-available foreign vaccines, which they should evaluate.

We adopt a tabular presentation that outlines the attributes of vaccines, following much recent research (Motta, 2021; Kreps et al., 2020; Kreps and Kriner, 2021; Stöckli et al., 2022). We adopt a single-profile design, showing one vaccine profile at a time to respondents, unlike previous studies that use a paired-profile design. This approach closely matches our scenario of interest where the *first available* vaccine does not have a direct competitor. As such, the single-profile design is chosen to increase external validity and to make a more natural evaluation process for respondents. There is a concern that this design may not perform as effectively as a paired-profile design, as suggested by Hainmueller (2015), who found that although single-profile designs fare well, they are less effective due to respondents' satisficing behavior. In the discussion section, we will revisit this concern and evaluate the potential impacts of this design choice.

The attributes assigned to our hypothetical vaccines are derived from Kreps et al. (2020), but we extend the list to encompass the odds of effectiveness against mild symptoms and the number of required injections. For a comprehensive overview of all attributes and their potential variations, refer to Table 1. Every attribute's realization, except for the WHO endorsement and the country of origin, is drawn randomly from a uniform distribution. Each participant sees a total of 12 vaccine profiles in sequence.

The bottom two attributes in Table 1 are key for testing our hypotheses. First, we randomly vary whether or not the vaccine receives an endorsement from the WHO (using "Yes" vs. "No" language). Second, we randomly assign the vaccines' countries of origin. As we are conducting the experiment in the United States, we focus only on vaccines produced outside the United States, consistent with the idea that for almost everyone in the world, the earliest vaccine in a new pandemic will come from abroad. China, Russia, Germany, and the U.K. are all suitable vaccine-developing nations, as they have all produced widely used COVID-19 vaccines. However, they vary in terms of perceived favorability: the former two are among U.S. citizens' most unfavorable countries, whereas Germany and the U.K. among the most favorable. A Gallup survey from early 2023 shows that 80% and 86% of U.S. citi-

Table 1
Attributes and Possible Realizations for Vaccine Profiles.

Vaccine attribute	Potential realizations
Efficacy against severe illness	50% 70% 90%
Efficacy against minor illness	10% 20% 30%
Odds of minor side-effects	1 in 10 1 in 50 1 in 100
Odds of major side-effects	1 in 10,000 1 in 100,000 1 in 1,000,000
Number of injections	One Two Three
Vaccine type	mRNA Weakened virus Viral vector Protein subunit
Protection duration	6 months 1 year 2 years
Endorsed by World Health Organization	Yes No
Country of vaccine origin	China Russia Germany United Kingdom

zens view Germany and the U.K. favorably, respectively, but only 15% and 9% do toward China and Russia, respectively (Gallup, 2023). For the main analyses, we created a dichotomous indicator corresponding to whether the vaccine originated from an unfavorable (1 if Russia or China) or favorable origin (0 if Germany or U.K.).

We force the number of times that participants see each country and each WHO endorsement realization to be identical. We also randomize the order of these two key attributes (WHO endorsement and vaccine's country of origin), while maintaining a fixed sequence for the remaining attributes. This decision was carefully made to balance the need for randomization of the attributes that we hope to better understand in the present research, with the aim of minimizing the cognitive load burdens placed on respondents.

The two key attitudes under examination are how people feel toward the vaccine, which will be our mediating variable, and what people's policy preferences are given to the particular vaccine. First, below each vaccine profile, we ask "[h]ow do you feel toward Vaccine [X] in the context of the flu pandemic situation?", a standard feeling thermometer question. The choice options are nine levels on the Likert scale: "Extremely cold", "Very cold", "Cold", "Somewhat cold", "Neither cold nor warm", "Somewhat warm", "Warm", "Very warm", and "Extremely warm." Our decision to employ a feelings-based measure, as opposed to solely focusing on direct questions about efficacy or side effects (Chiang et al., 2022), allows us to capture not only the multidimensional nature of vaccine quality, including aspects like duration of protection and dosage requirements, but also the complexity of vaccine perceptions, as supported by prior research (e.g., Callaghan et al., 2021; Gadarian et al., 2021; Jones and McDermott, 2022).

Second, we capture a respondent's policy preferences, which serve as our primary outcome variable, by asking "[if] the only vaccine option for the next six months is the above vaccine, would you be in favor of or against the U.S. government making it available to people living in the United States?" The answers are gathered via a seven-level Likert scale, ranging from "strongly against" to "strongly in favor." For ease of interpretation, we treat both Likert scales as approximately linear and rescale them to have a mean of zero and a standard deviation of one.

2.3. Statistical models

Our hypotheses require us to answer questions about treatment as well as about mediation and moderation effects. Leaving aside moderation effects for a moment, we begin by describing how we obtain the causal mechanism estimates. Mediation effects are about answering to which extent a treatment effect is transmitted via a particular channel, which we approach by using the framework set up in Imai et al. (2011) and Imai et al. (2010). We posit that feelings toward a vaccine mediate how the country of origin affects support for a government to purchase the vaccine.

Let $Y_\iota(t, M(t))$ be the policy preference a person ι would have if they had treatment t (1 if unfavorable, 0 if favorable origin) and expressed the mediator attitude M, which itself is a function of the treatment, t. Naturally, the total effect, the usual quantity of interest in experiments, is $\tau_\iota = Y_\iota(1, M(1)) - Y_\iota(0, M(0))$. Imai et al. (2011) and Imai et al. (2010) define a causal mediation effect by taking the effect of the treatment on the outcome when the realization of the mediator changes from its value of $t = 0$ to $t = 1$, holding constant the value of the treatment; that is, $\zeta_\iota(t) = Y_\iota(t, M(1)) - Y_\iota(t, M(0))$. Analogously, the direct effect is the effect of the treatment on the outcome due to going from $t = 0$ to $t = 1$, which holding the mediator realization at t, or $\delta_\iota(t) = Y_\iota(1, M(t)) - Y_\iota(0, M(t))$.

Practically, we are working with two statistical models that help us generate the constituent quantities for the quantities of interest. M_{ij} is the observed value of the mediator (feeling thermometer score) that respondent i gives for the j^{th} vaccine they evaluated; the treatment T_{ij} indicates whether the vaccine was produced in a unfavorable country (1) or not (0); Y_{ij} is the policy preference; and last X_{ij} is a collection of additional variables (demographics, other vaccine attributes, intercept) that we explain below. Assuming Gaussian errors for the mediator and the outcome, we obtain these linear regression models, for which we can estimate parameters based on the collected data:

$$M_{ij} = \alpha_1 T_{ij} + X_{ij}\delta + \epsilon_{ij}$$

$$Y_{ij} = \beta_1 T_{ij} + \beta_2 M_{ij} + X_{ij}\gamma + \nu_{ij}.$$

So far, we have sidelined our theoretical expectation that a WHO endorsement mitigates—i.e., moderates—the country-of-origin effects. Relying on the framework by Bansak (2021), we can estimate the moderation effects by subsetting the data to realizations with WHO endorsements and without in turn, obtaining τ_π^w, δ_π^w, and ζ_π^w, with superscript $w \in \{0, 1\}$ denoting the separate estimates based on the WHO endorsement (1) or its absence (0). Second, we compare each total, direct, and indirect effect for $w = 1$ against $w = 0$. Since our moderator is randomized, the approach causally identifies the moderation effects.

Given the linearity of the two models, the direct and indirect effects, as well as their moderations, are simple functions of coefficients; therefore, we can drop the subscripts. The indirect effect is simply $\zeta_w = \beta_1^w$ and the direct $\delta_w = \beta_2^w \alpha_1^w$. The moderations of each effect are the differences between their estimates based on the two WHO endorsement realizations—i.e., $\Delta(\zeta) = \beta_1^1 - \beta_1^0$ and $\Delta(\delta) = \beta_2^1\alpha_1^1 - \beta_2^0\alpha_1^0$.

While randomization identifies estimable causal treatment effects, we want to increase statistical precision and later examine the heterogeneity of treatment, mediation, and moderation effects. Therefore, the statistical models are augmented by a covariate vector, X_{ij}. First, it includes standard demographic variables, such as age, gender, partisan affiliations, and trust in the U.S. government and big pharmaceutical companies (respectively). Further, we create simple indices for how vulnerable a respondent is to the disease (based on the medical conditions of the respondent, such as cancer or diabetes, and the age) and

Table 2
Coefficients for main estimates. The number is the point estimate, the range below the 95% confidence interval.

	Feeling toward vaccine		Support for government buying vaccine			
	No WHO	WHO	No WHO	WHO	No WHO	WHO
Unfavorable country	-0.45	-0.49	-0.45	-0.49	-0.06	-0.07
	[-0.50; -0.40]	[-0.54; -0.44]	[-0.50; -0.40]	[-0.54; -0.44]	[-0.08; -0.04]	[-0.09; -0.05]
Vaccine feeling					0.87	0.85
					[0.85; 0.90]	[0.83; 0.87]
Efficacy major, 50%	-0.38	-0.41	-0.34	-0.37	-0.01	-0.02
	[-0.43; -0.32]	[-0.46; -0.35]	[-0.39; -0.28]	[-0.42; -0.31]	[-0.04; 0.02]	[-0.05; 0.01]
Efficacy major, 90%	0.25	0.29	0.24	0.25	0.03	0.00
	[0.19; 0.31]	[0.24; 0.34]	[0.19; 0.29]	[0.20; 0.30]	[0.00; 0.05]	[-0.03; 0.03]
Efficacy minor, 10%	-0.01	-0.02	-0.01	-0.02	0.00	0.00
	[-0.06; 0.04]	[-0.07; 0.03]	[-0.06; 0.05]	[-0.07; 0.03]	[-0.03; 0.03]	[-0.03; 0.03]
Efficacy minor, 30%	0.00	0.03	0.01	0.03	0.00	0.01
	[-0.05; 0.05]	[-0.02; 0.08]	[-0.05; 0.06]	[-0.02; 0.08]	[-0.02; 0.03]	[-0.02; 0.03]
Major side effects, high	-0.05	-0.09	-0.04	-0.09	0.00	-0.01
	[-0.10; 0.01]	[-0.15; -0.04]	[-0.09; 0.02]	[-0.14; -0.04]	[-0.02; 0.03]	[-0.03; 0.02]
Major side effects, low	0.15	0.09	0.14	0.09	0.01	0.01
	[0.10; 0.20]	[0.04; 0.15]	[0.09; 0.19]	[0.04; 0.13]	[-0.01; 0.04]	[-0.02; 0.03]
Minor side effects, high	-0.02	0.03	-0.01	0.02	0.01	0.00
	[-0.07; 0.02]	[-0.02; 0.08]	[-0.06; 0.04]	[-0.03; 0.07]	[-0.02; 0.03]	[-0.03; 0.02]
Minor side effects, low	0.01	0.04	0.01	0.05	0.00	0.02
	[-0.04; 0.06]	[-0.01; 0.09]	[-0.04; 0.07]	[0.01; 0.10]	[-0.03; 0.03]	[0.00; 0.04]
Protection, 1 year	0.05	0.05	0.04	0.08	0.00	0.04
	[0.00; 0.10]	[0.00; 0.10]	[-0.01; 0.09]	[0.03; 0.14]	[-0.03; 0.03]	[0.01; 0.07]
Protection, 2 years	0.13	0.10	0.11	0.13	0.00	0.04
	[0.08; 0.18]	[0.05; 0.15]	[0.06; 0.16]	[0.08; 0.18]	[-0.03; 0.03]	[0.02; 0.07]
Type, viral vector	0.06	-0.04	0.06	0.00	0.01	0.03
	[0.00; 0.12]	[-0.09; 0.02]	[-0.01; 0.13]	[-0.06; 0.06]	[-0.02; 0.04]	[0.00; 0.06]
Type, mRNA	0.03	-0.06	0.03	-0.04	0.00	0.02
	[-0.03; 0.09]	[-0.12; -0.01]	[-0.04; 0.09]	[-0.10; 0.02]	[-0.03; 0.03]	[-0.02; 0.05]
Type, protein subunit	0.04	0.01	0.03	0.03	0.00	0.02
	[-0.03; 0.09]	[-0.05; 0.06]	[-0.03; 0.09]	[-0.02; 0.09]	[-0.03; 0.03]	[-0.01; 0.05]
Injections, one	0.06	0.06	0.04	0.06	-0.01	0.01
	[0.01; 0.11]	[0.01; 0.10]	[-0.01; 0.10]	[0.01; 0.11]	[-0.04; 0.01]	[-0.02; 0.04]
Injections, three	-0.08	-0.08	-0.07	-0.03	0.00	0.03
	[-0.13; -0.02]	[-0.13; -0.03]	[-0.12; -0.02]	[-0.08; 0.02]	[-0.03; 0.02]	[0.00; 0.06]
Trust, big pharma	0.01	0.09	0.01	0.10	0.00	0.03
	[-0.10; 0.11]	[-0.02; 0.18]	[-0.11; 0.12]	[0.00; 0.20]	[-0.06; 0.06]	[-0.02; 0.07]
Trust, government	0.08	0.13	0.06	0.09	-0.01	-0.01
	[-0.03; 0.18]	[0.04; 0.22]	[-0.04; 0.16]	[0.01; 0.18]	[-0.06; 0.04]	[-0.05; 0.03]
Vulnerability	-0.06	-0.01	-0.14	-0.12	-0.09	-0.10
	[-0.32; 0.18]	[-0.24; 0.23]	[-0.41; 0.10]	[-0.34; 0.11]	[-0.23; 0.04]	[-0.22; 0.02]
Anti-vaccine	-1.25	-1.46	-1.16	-1.38	-0.07	-0.13
	[-1.43; -1.08]	[-1.64; -1.27]	[-1.34; -0.95]	[-1.56; -1.19]	[-0.18; 0.03]	[-0.22; -0.03]
Age	0.00	0.00	0.00	0.00	0.00	0.00
	[-0.01; 0.00]	[-0.01; 0.00]	[-0.01; 0.00]	[-0.01; 0.00]	[0.00; 0.00]	[0.00; 0.00]
Gender, male	0.10	0.04	0.14	0.07	0.05	0.04
	[0.03; 0.17]	[-0.03; 0.11]	[0.06; 0.21]	[-0.01; 0.14]	[0.01; 0.09]	[0.00; 0.08]
Education, university	0.01	0.01	0.02	-0.01	0.01	-0.02
	[-0.06; 0.08]	[-0.06; 0.07]	[-0.06; 0.09]	[-0.08; 0.05]	[-0.03; 0.05]	[-0.05; 0.02]
Party, Democrat	0.16	0.19	0.16	0.19	0.02	0.02
	[0.07; 0.25]	[0.11; 0.28]	[0.08; 0.26]	[0.10; 0.28]	[-0.02; 0.07]	[-0.02; 0.06]
Party, Republican	0.01	-0.03	-0.02	-0.07	-0.04	-0.04
	[-0.07; 0.10]	[-0.12; 0.05]	[-0.12; 0.06]	[-0.15; 0.02]	[-0.09; 0.01]	[-0.09; 0.01]
Observations	6,660	6,660	6,660	6,660	6,660	6,660

how skeptical the respondent is vis-à-vis vaccines (based on a series of agree/disagree statements and whether one took a vaccine against COVID-19). The question wordings and usages are discussed in Section B in SI. Second, a series of indicators for all vaccine attributes and their realizations are shown in Table 1.

All standard errors are estimated using a cluster bootstrap to adjust for the fact that each respondent evaluated multiple profiles. Imputation was used to fill in some minor missing data (14 people did not provide their age, even fewer failed to give some disease information, and one person omitted stating their party affiliation or policy preferences.)

3. Main results

Table 2 shows the linear regression models underlying the main results of the paper. From left to right, each successive pair of columns gives the model estimated on data subset to vaccines with WHO endorsement (odd-numbered results columns) and without it (even-numbered). Let us first examine the effect of the favorable versus unfavorable country of origin on the feelings toward a vaccine. Columns 1-2 in Table 2 give the results: when a vaccine is presented as being developed by an unfavorable country, either China or Russia in our study, feelings toward the vaccine are colder compared to a vaccine of German or U.K. origin. As the outcome variable is scaled to a standard deviation of one, the estimated coefficients on the indicator variable show a decline in warmth by 46-49% of the standard deviation. The range below the point estimate is the 95% confidence interval, which excludes zero, denoting statistical significance. This country-of-origin effect holds for both WHO endorsed and non-WHO endorsed vaccines, which are very close in magnitudes and uncertainty. Therefore, mod-

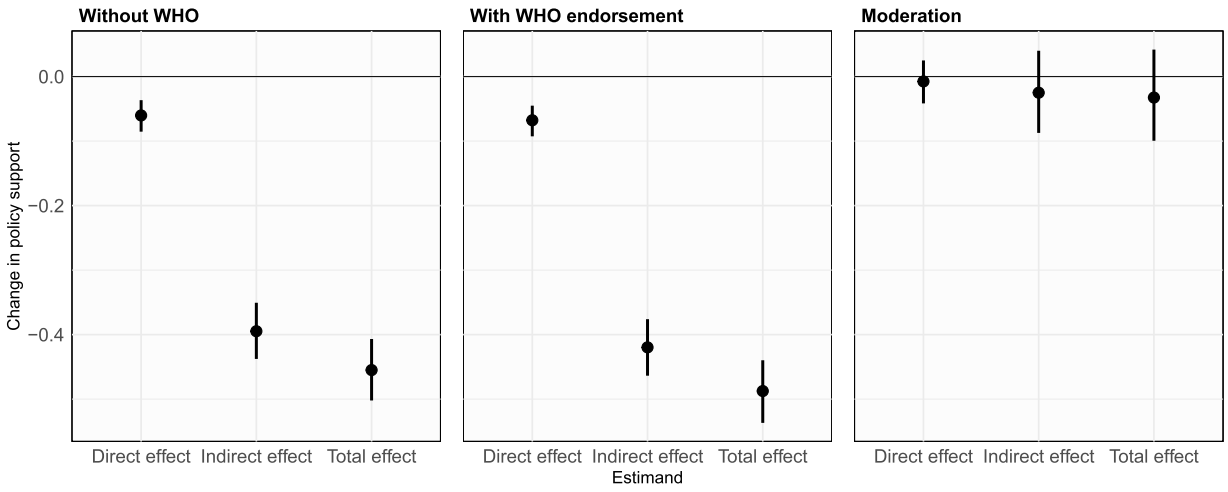

Fig. 1. Country-of-origin Effects on Policy Preferences and Causal Mediation. The causal mediation estimands and magnitudes are given on the x- and y-axes, respectively. Each dot gives the mean estimate, the range the 95% confidence interval. The two panels on the left show the results based on the samples subset to vaccines without (first) and with WHO endorsement (second). The third panel gives the moderation effects, which are the differences between the estimates from the first two panels.

eration of the country-of-origin effect on vaccine preferences through a channel of feelings toward a vaccine is small at best.

Columns 3-4 in Table 2 have the support for procuring a vaccine as their outcome variables. In this specification, we omit the mediator (i.e., vaccine feelings) from the models, which means we can interpret the coefficients on an untrustworthy origin as the total effect. We find that comparing a Russian or Chinese vaccine against a German or U.K. one leads to reduced support for purchasing by 46-49% of the standard deviation of the policy preferences. Once again, for each realization of the WHO endorsement, we observe very similar results.

We estimate another set of models that add the mediator to the equation for the policy preference models, with results in Columns 5-6 of Table 2. We find that the feeling toward the vaccine affects the policy preferences significantly and sizably. We also find that the effect of the unfavorable origin is also detectable in these models, suggesting that we have direct and indirect mediation effects. Once again, estimates for the two WHO scenarios look quite similar, suggesting very limited moderation.

Even though the results discussed thus far suggest a rather clear picture of the mediation and moderation effects, we want to simulate them formally so that estimation uncertainty is also adequately accounted for. The estimation relies on a non-parametric bootstrap. We show these results in Fig. 1. Each x-axis shows the estimands while the y-axis the change in support for the government purchasing a vaccine.

Let us start with the left and middle panels of the figure. In each, we show direct (δ), indirect (ζ), and total effects (τ) comparing an unfavorable to a favorable vaccine origin when there is no WHO endorsement (left) and when there is not (middle). We see that the indirect effects (i.e., the effects of origin favorability that are mediated through vaccine feelings) account for the predominant portion of the total effect. The panel on the right gives the moderation of the three effects when going from no WHO endorsement to an endorsement. For each of the three effects, the WHO makes no real difference with even the mean effects minuscule, which are not statistically different from zero.

All in all, we find clear, consistent evidence that the country-of-origin effect substantially mediates through feelings toward the vaccine, which is largely unaffected by endorsements from the WHO.

4. Moderation analyses & robustness checks

We extend our main analysis in various ways to examine how the main results change for different subgroups of substantive interest and thereby also probe the robustness of the main findings.

4.1. Vulnerable population

Vaccines are particularly important for those most vulnerable to the disease. We repeat our main analysis using only the subset of respondents who score above the mean in the vulnerability index tailored to the hypothetical disease scenario (see Section B in SI). By construction, respondents in this subset are less healthy compared to those in the full sample—for example, they are 18 percentage-points more likely to have obesity, 8 percentage-points more likely to have diabetes, 7 percentage-points more likely to have auto-immune diseases, and 8.5 years older than the general population—but otherwise quite similar on other socio-demographic observables (e.g., education, political ideology). As we subset the data by the realization of a non-randomized moderator, we are examining treatment heterogeneity (Bansak, 2021).

The top row of Fig. 2 shows the results for this important subset of respondents who would be particularly vulnerable to the flu in our scenario. We find almost identical patterns as before, with mean direct and total effects being slightly higher than those in the full sample. Again, the WHO plays little role in moderating these effects.

4.2. Vaccine persuadability

We understand individuals vary in their inclination towards vaccines overall, which probably impacts their receptivity to persuasion by variations in quality, country-of-origin, or WHO endorsement. Those who hold strong pro-vaccine or anti-vaccine attitudes may be less persuadable due to their already firmly established feelings toward vaccination. Those with less firm commitments may be comparatively more open to persuasion and represent an important subset. WHO endorsement could thereby moderate the country-of-origin effect for this group, despite limited evidence from the full sample.

We subset the data to those above the median but below the 95^{th} percentile of the vaccine skepticism index (see Section B in SI), deviating slightly from the setup we outlined in the pre-analysis plan. Respondents in this subset are less likely to have taken at least one shot of a COVID-19 vaccine than in the full sample (by 25 percentage-points) and more likely to hold attitudes hostile to vaccines. The only other difference between this subset and the full sample is that they are less likely to self-identify as Democrats (−15 percentage-points) and slightly more likely to self-identify as Republicans (+9 percentage-points) while they are similar on other dimensions. The second row of Fig. 2 shows the results—the treatment, mediation, and moderation effects look very similar to the main results, albeit at considerably reduced magnitudes.

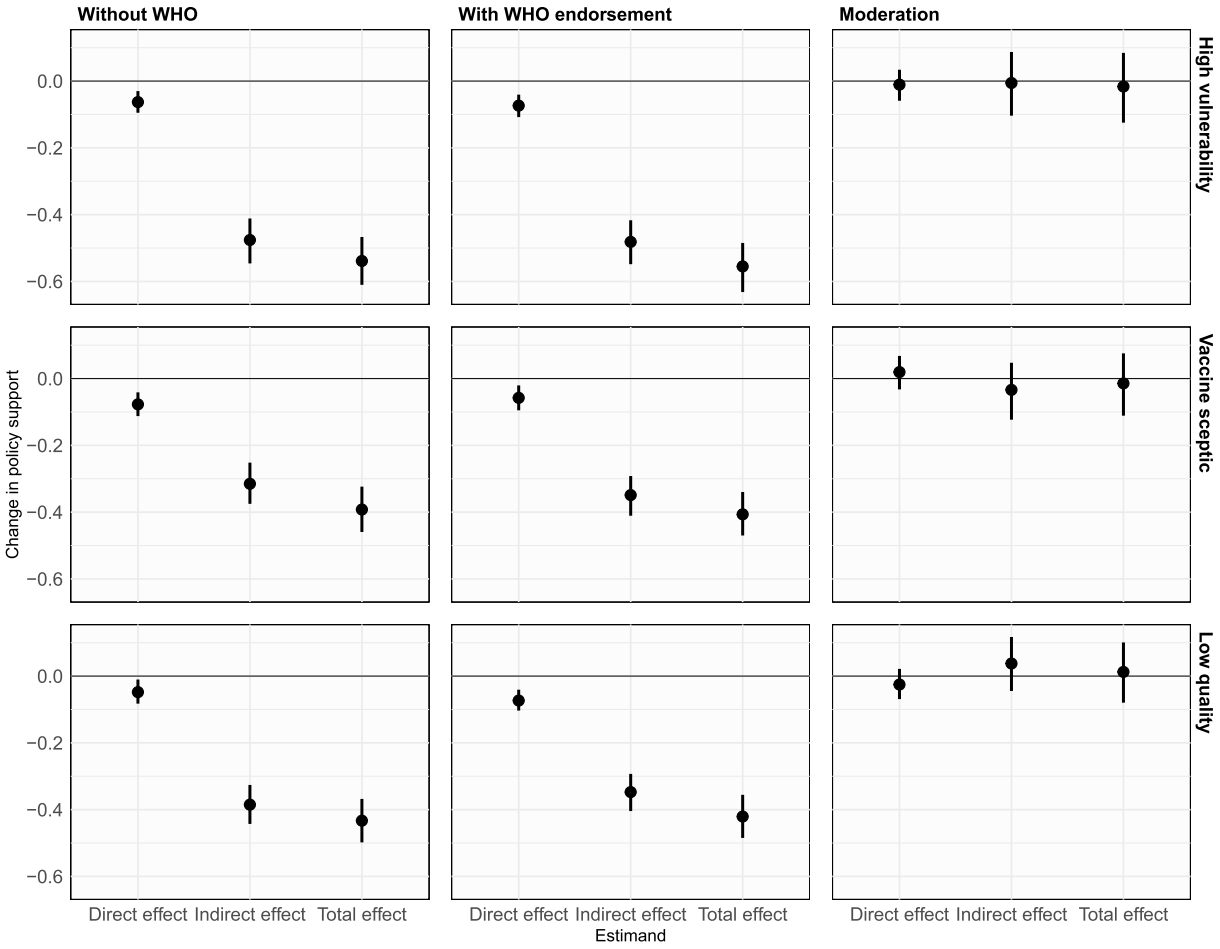

Fig. 2. Country-of-origin effects for the Vulnerable, those Skeptical of Vaccines, and Poor Quality Vaccines. Each row of panels is built the same way as for Fig. 1. The underlying models summarized in Tables A.1, A.2, and A.3.

4.3. Vaccine quality

We started our study by arguing that early vaccines, which are particularly valuable from a public health perspective, might be of poorer quality due to pressures and incentives to make the first one available. Therefore, examining country-of-origin and WHO effects for such vaccines of lower quality are particularly important. Recall that the vaccine quality was determined by all but the bottom two attributes in Table 1, stemming from the vaccine design (number of injections or vaccine type) or from the clinical trial results. We think these seven variables constitute the "objective" vaccine quality.

It is not straightforward to objectively identify vaccines of poorer quality as these attributes all contribute to vaccine quality and involve necessary trade-offs. For example, a vaccine that produces a low chance of experiencing side effects coupled with high efficacy is likely ideal. Less clear, however, is whether a vaccine with low side effect risks and low efficacy is "better" than one with high efficacy and high side effects.

To greatly simplify this subjective rating task, we developed an approach to reduce the seven dimensions of quality to a single quantity. In spring 2023, we visited a 2nd year class of MD students at one of the authors' university who serve as an expert sample. After showing them the same background information about the flu pandemic, they were asked to pick the "better vaccine" in 20 rounds of pairs of vaccine profiles that mirrored those presented in our experiment (which omitted the WHO endorsement and country of origin). Deleting missing responses, we have data from 3,478 vaccine evaluations from 88 MD students. Using indicators for attribute realizations, we fit a series of Bernoulli-Cauchy models to the data, which we weight using Bayesian Model Averaging (Raftery et al., 1997; Montgomery and Nyhan, 2010). We obtain a predicted probability for each possible vaccine profile, which we call the vaccine quality going forward. See Section F in SI for more detail.

Only using all vaccine profiles below the mean probability, we repeated the mediation and moderation analyses. Compared to all the vaccines in our experiment, these low-quality vaccines have worse major side effects, are less effective against major illnesses, and have feelings and policy support by about 20% of the respective standard deviation while they are similar on other dimensions. The bottom row of panels in Fig. 2 confirms that the treatment patterns are similar, albeit at slightly reduced magnitudes.

4.4. Specific pairs of favorable and unfavorable origins

In our main analysis, we have pooled across all four pairs of countries of origin. But, the results may change when particular countries of origin are considered. We repeated the analyses using each pair of favorable (Germany, U.K.) and unfavorable (China, Russia) countries while we have no particular theoretical expectations about particular countries or their pairs. Fig. A.3 in SI gives the estimates, which are essentially indistinguishable from the main findings.

4.5. Alternative coding

Assuming linearity for the outcome and the mediator variables gives us ease of interpretation, but potentially comes at the cost of modeling assumption violations. We therefore re-estimate all models underlying

our main results by turning the vaccine feeling and the support for the government to procure the vaccine into ordinal variables, relying on ordered probit models in the calculation of direct and indirect favorability effects. Accordingly, we obtained causal mediation and moderation estimates for the probability of each level of support for the government's pursuit of the vaccine. Fig. A.4 in SI gives the results. Across the ordinal levels of support, we find a remarkable "straight line": the probability of being "strongly against" buying the vaccine from the unfavorable sources increases by about 10 percentage-points, whereas "strongly in favor" decreases by about 5 percentage-points, with other total and direct effects in between the extreme levels falling in between. Again direct effects are almost absent, and some levels' moderation effects depart statistically significantly from zero, but at negligible levels.

5. Conclusion

In this piece, we presented novel experimental evidence of vaccine purchasing policy favoritism toward initial vaccines produced in countries that Americans deem to be favorable instead of unfavorable. We further offer a mechanism by which this bias occurs, by documenting that the negative affect toward vaccines produced in unfavorable countries mediates the effects of the country-of-origin on policy preferences.

In addition to the large substantive magnitude of these effects, we find that—although we might expect endorsement from widely respected global health agencies that represent public health interests across a diverse range of national contexts, like the WHO, to mitigate country-of-origin effects—preferences for vaccines produced in countries deemed favorable persist irrespective of WHO endorsement. Both country-of-origin effects, and the failure of WHO endorsements to combat them, persist irrespective of objective vaccine quality as rated by medical professionals, as well as individual-level vaccine skepticism and vulnerability to severe infection.

5.1. Limitations

Of course, our work is not without some important limitations. Chief among them is the idea that we are drawing inferences about the general effects of vaccine-producing countries' favorability on the basis of a single study conducted in a single national context (the United States); and a vaccine-producing national context, at that. A new study demonstrates that experimental results from the U.S. sample concerning foreign policy preferences and public perceptions of foreign countries generalize to a diverse range of cross-national contexts (Bassan-Nygate et al., 2023). To bolster the generalizability of our findings, especially beyond the United States, it is crucial to replicate our work cross-nationally—especially in vaccine-consuming countries that do not typically produce vaccines of their own.

Additionally, while the WHO's endorsement is found to have limited impact, other strategies may potentially counteract country-of-origin effects. During the COVID-19 pandemic, vaccine-producing countries such as Russia and China adopted strategies including production outsourcing, conducting clinical trials in potential markets, and technology transfers, in part due to concerns regarding their low credibility (Suzuki and Yang, 2023). Although Barceló et al. (2022) found people prefer vaccines manufactured locally, even when the technology originates abroad, the efficacy of alternative strategies to combat broader reputation remains unexplored. This question warrants further inquiry in future research.

We further caution that our results are derived from a single set of experimental trials. First, while we believe that the vaccine attributes and the corresponding levels of those attributes in our study are both theoretically well-grounded and reasonably exhaustive, we nevertheless recognize that there are many different ways in which vaccines' clinical properties and socio-political reputations might vary. Thus, we encourage researchers to continue to replicate our work not only in a diverse range of national contexts but also through amended conjoint experimental protocols.

Second, unlike typical conjoint studies, we used a single-profile design, which might be seen as underestimating attributes like the vaccine's country of origin due to respondent satisficing Hainmueller et al. (2015). This could partially explain the limited moderating effect of WHO endorsement in our results. However, the significant impact of both the country of origin and WHO endorsement in our study indicates that respondents were actively engaged, countering the notion that satisficing greatly influenced our findings. Therefore, we maintain that satisficing does not undermine the validity of our findings.

Third, our study's results could be influenced by the survey's timing, as public attitudes towards COVID-19 have evolved, potentially leading to a desensitization to pandemic threats. This shift in concern could reflect a temporary state in U.S. health opinions, capturing a pre-pandemic mindset with possibly less support for government procurement of foreign vaccines, depending on the fluctuating pandemic conditions. Alternatively, if this reduced concern is more permanent—possibly due to the politicization of science and vaccines—, it might affect public support for government vaccine procurement policies even during a global pandemic. While these shifts in perception are likely to have some impact on our results, we cannot definitively predict how it would specifically influence the effects of the vaccine's country of origin or the moderating role of WHO endorsement in our study. For this reason, we think it is important that scholars continue to monitor how concern about past and (potential) future health crises might shape public opinion about vaccines, vaccine policy, and trust in relevant government/non-government agencies.

Overall, while our findings might be limited in generalizability, we nevertheless believe that they offer important insights into both the nature and consequences of vaccine country-of-origin effects in an understudied area (i.e., policy about the procurement of initial vaccines). We look forward to efforts to expand on this research in the future.

5.2. Discussion

Our work advances prior research on country-of-origin effects in at least four ways. First, our work shifts focus from the individual act of vaccinating (vaccine uptake intentions; as is common in most prior research on the subject) to policies regarding which vaccines countries ought to purchase in a pandemic. As such, our argument and results offer a potential explanation, grounded in domestic politics and public opinion, for government decisions to pass on early foreign vaccine orders (e.g., U.S. government's decision not to purchase the Sputnik V vaccine mentioned in the introduction) and, alternatively, to invest more in domestic vaccine production.

Second, recognizing the significant role and impact of *initial* vaccines, our study emphasizes scenarios where governments are confronted with decisions regarding the procurement of initial foreign vaccines, even those that might be of lower quality. At the same time, this required us to shift focus from a specific emphasis on the COVID-19 pandemic to a general future pandemic scenario, thereby increasing the generalizability of our findings.

Third, we provide a psychological mechanism by which the country-of-origin effects occur—i.e., that vaccines produced in less-favorable countries tend to produce greater negative affect toward the vaccines, which in turn fuels vaccine favoritism in procurement policy. This enables us to better understand how vaccine properties (including their national context) influence not only individual behavior but also the incentives they provide for elected officials to take (or forego taking) policy actions that impact vaccine availability nationwide.

Fourth, and perhaps most importantly, we add nuance to existing insights about the effect of WHO endorsements by considering how both individual-level factors and vaccine quality might moderate their effectiveness. Alarmingly, our work warns that even objectively superior vaccines—from a clinical safety and efficacy standpoint—cannot fully

eliminate country-of-origin effects or inspire public willingness to defer to WHO recommendations. As in other studies, the path from WHO endorsements to tangible outcomes is not without obstacles (Bayram and Shields, 2021; Kobayashi et al., 2023).

There are several potential reasons why our findings on WHO endorsement may differ from those reported by Sheen et al. (2023), including differences in geographical context, pandemic conditions, and experimental design, making direct comparisons complex. Also importantly, the findings of Sheen et al. (2023) imply that the efficacy of WHO endorsement depends critically on the level of trust people place in the organization. That said, a notable distinction in our experimental approach merits discussion. Unlike Sheen et al. (2023), who used a 2×2 factorial design focusing on the vaccine's country of origin and WHO approval, our experiment includes these factors among nine attributes to assess vaccine quality. Media coverage typically includes more than the vaccine's country of origin and WHO approval, offering some level of detail about vaccine attributes and test results (Meyer et al., 2016; Quintero Johnson et al., 2011). Then, our experiment may offer a more realistic assessment compared to the more focused approach of Sheen et al. (2023), potentially positioning their findings as representing the maximum effect of WHO endorsement.

Put simply, attitudes toward vaccines could play an important role in establishing electoral incentives by which politicians and bureaucrats may procure one foreign vaccine over another (Mayhew, 2004). Histories of interstate violence may explain these in part (Kobayashi et al., 2022). Mitigating them might be possible as U.S. and German respondents, many just one generation removed from one of history's bloodiest wars, make little difference between vaccines from the other country (Kobayashi et al., 2021). Of course, the policy implications are unclear from that one uplifting example.

Given the relative inefficacy of endorsements from the WHO at mitigating country-of-origin effects, we instead propose that vaccine-producing countries ought to regularly take stock of their global public image in a wide variety of cross-national contexts (e.g., through public opinion polling like Smith (2021)), and take action to improve their trustworthiness in areas where they are held in comparatively less esteem. Our results do not rule out that the WHO could not play an important role in this manner.

Our research, therefore, argues for a broader understanding of "vaccine diplomacy"—i.e., the processes by which vaccine-producing and vaccine-consuming countries engage in cross-national vaccine provision and/or administration (Suzuki and Yang, 2023; Vadlamannati and Jung, 2023). It should be re-conceptualized to include not only the degree to which countries engage in the transfer of life-saving pharmaceuticals but to encompass the broader national reputations of vaccine-producing countries in the eyes of those receiving the vaccines. Legacies of military aggression, unfavorable trade policies, and other aspects of interstate relations, even though not directly related to vaccination, can shape public acceptance of vaccines by influencing public trust in vaccine-producing countries, just like foreign health policy can (Goldsmith et al., 2014; Kobayashi et al., 2022; Martinez-Bravo and Stegmann, 2022; Lowes and Montero, 2021). Vaccine diplomacy, in other words, is not just about specific actions related to vaccine distribution but ought to be considered to be the result of interstate relations in general.

Whereas vaccine diplomacy considers the producing country's side, we have to return to the fundamental question in vaccine-taking country of why aspects of a vaccine are so important. After all, few people know where a flu, MMR, or DTP vaccine comes from. This raises the important question, which to our knowledge has received scant attention: *when* is a vaccine and its origin politicized? We would speculate that politicians, who are important cue-givers generally, may have incentives to claim credit for and tout a powerful vaccine rolled out under their auspices, but a challenger may sow doubt if it is electorally advantageous.

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Institutional Review Board

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CRediT authorship contribution statement

Tobias Heinrich: Writing – review & editing, Writing – original draft, Funding acquisition, Formal analysis, Conceptualization. **Yoshiharu Kobayashi:** Writing – review & editing, Writing – original draft, Funding acquisition, Conceptualization. **Matthew Motta:** Writing – review & editing, Writing – original draft, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors have no conflicts of interest to declare.

Data availability

Our data/code will be made available on Heinrich's personal website.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used OpenAI's ChatGPT (GPT-4 version) to improve the manuscript's readability. After using this service, the author reviewed and edited the content as needed and takes full responsibility for the content of the publication.

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Appendix A. Supplementary material

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.socscimed.2024.116766.

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