Privileging Sciences: Vaccine Endorsement at the World Health Organization

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Abstract

International organizations (IOs) can use scientific evaluation to channel the behavior of market-oriented actors for IOs' own institutional goals. While previous research acknowledges the role of IOs as an epistemic community in shaping cooperation by states, the same logic may not apply to profit-driven actors. Investigating the case of vaccine endorsement by the World Health Organization (WHO), we argue that IOs can use vaccine prequalification—a procedure for procurement purposes in the United Nations—to induce firms' R&D investment in vaccines targeting low-income countries, which are historically underinvested due to the geographic mismatch in the demand and supply of vaccines. Empirically, we find that vaccines targeting diseases with more unequal geographic distribution are more likely to receive priority in WHO's prequalification procedure. Moreover, the WHO's prioritization can lead to more clinical trials, a measure of firms' investment in vaccine R&D. This paper reveals the market implications of scientific evaluation by IOs.

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1 Introduction

Scientific advancements are constantly evaluated. In an increasingly specialized world, states delegate standard-setting authority to international organizations (IOs) that are staffed with experts. How do IOs evaluate scientific information? What drives the consideration in the evaluation?

Vaccine endorsement by the World Health Organization (WHO) provides a unique case to study how IOs evaluate scientific advancements. Evaluation of vaccines requires advanced technical capacity and profound time investment, which makes delegation to the WHO much more efficient compared with other scientific advancements. Endorsement provides information that enhances governments' confidence in the effectiveness and safety of a specific vaccine and thus increases market demand for the vaccine. Given the demand-enhancing effect of vaccine endorsement, the WHO can strategically design the endorsement standard to channel pharmaceutical firms' investment to specific purposes. By studying the characteristics of the vaccines that the WHO prioritizes to endorse, we can infer the driving force of the scientific evaluation at the WHO.

We argue that the concern to promote development drives the WHO's scientific evaluation. The development of vaccine technology without WHO intervention is biased in favor of advanced economies, which is primarily driven by monetary incentives. Vaccines for diseases that are prevalent in developed countries have a larger market demand, which increases the marginal returns of the investment in the research and development (R&D) of such vaccines. For the same reason, pharmaceutical firms may not have as strong incentives to invest in vaccines for diseases concentrated in least developed regions due to small market demand. This explains why the development of COVID-19 vaccines is fast and effective, while it is so slow for Ebola vaccines. To address this problem of vaccine underinvestment, the WHO can lower the endorsement standard for vaccines that target diseases prevalent in least developed regions. This can increase pharmaceutical firms' expectation of the return in investment in vaccine R&D. As a result, by reducing the endorsement standard for vaccines that serve

least developed regions, the WHO can induce more R&D investment in vaccines that target diseases in least developed regions.

To test this argument, we investigate the WHO's vaccine prequalification program—which aims to provide safety and effectiveness standards for procurement purposes—and examine whether vaccines that target diseases concentrated in the least developed regions are more likely to be prequalified and whether the WHO prequalification leads to more investment in vaccine development as is measured by the number of clinical trials. We first create a Gini index for the inequality of diseases based on the geographic distribution of affected population. We find that vaccines for diseases that are more unequally distributed around the world are more likely to receive high priority in the pre-qualification list. The result suggests that the WHO promotes scientific advancement with favoritism towards developing regions. Meanwhile, vaccines for diseases that are prioritized by the WHO attract more firm investments, which supports our argument that endorsement from the WHO facilitates downstream firm efforts. These results are consistent with the developmental model of scientific information production in IOs.

This paper makes two contributions. First, it contributes to the literature on the regulation of new technologies. Existing work suggests that the regulatory efforts can be shaped by domestic institutions (Mattli and Büthe, 2003), technocrats (Haas, 1992), private actors (Perlman, 2020), and countries in the Global North (Hai, 2023). In this paper, we propose a developmental model of the regulation of scientific advancements. Specifically, we argue that IOs promote scientific advancements with the consideration to promote the development of less wealthy regions. Second, it adds to our understanding of the role of IOs as an espitemic community in international cooperation (Haas, 1992). While the conventional understanding focuses on the mechanism of norms creation (Haas, 1989), our paper highlight the market implications of scientific evaluation, which empowers IOs as an epsitemic community.

2 Theory

Due to the increasing complexity of specialized knowledge, it is challenging for states to evaluate scientific advancements. This is especially true when it comes to the regulation of applying scientific advancements to real-world usage because various types of uncertainty may abound when the technology is in a new environment. For example, living organisms in biochemical products may function differently when the environment temperature changes, which may cause safety issues in the usage. Hence, states need to allocate resources and develop expertise to regulate the industrial application of scientific advancements, which may be challenging for states with limited regulatory capacity.

One solution to this regulation challenge is to delegate the authority of evaluation to IOs that are staffed with experts in the corresponding field (Hawkins et al., 2006). As an epistemic community, IOs can use their expertise to provide interpretations of the consequences of scientific advancements, reducing the uncertainty in the application in new environments. The diffusion of such information can influence the decision-making process of states by creating norms (Haas, 1992).

While it is widely acknowledged that IOs can influence states' behaviors through various mechanisms (Keohane, 1984; Dai, 2005; Kelley and Simmons, 2020; Koliev et al., 2021), it is not clear whether IOs can influence market-oriented actors, whose behaviors are driven by profits rather than norms (Lindblom, 1982). These profit-driven actors are the main actors connecting scientific advancements to real-world applications. In certain cases, these actors possess private information about the consequences of their products and may reveal such information only when it is profitable to do so (Perlman, 2020). This creates more hurdles for states to regulate the application of scientific advancements. Hence, it is important to understand whether delegating IOs with the authority of scientific evaluation helps states regulate their industries, especially for their investment in new technologies.

We argue that IOs can use scientific evaluation to influence the production of technology. As an epistemic community, IOs can disseminate information about their endorsement of

certain scientific advancements through their evaluation procedure, which provides a shared interpretation of the consequence of a new application (Hai, 2023). Such consensus provides a focal point in the decision-making process of downstream consumers of the product, which has implications for the profits of the producers of these scientific applications. By changing the expectations of their profits, IOs can change the investment decisions of these actors in different technologies. IOs can achieve this through three different aspects of the scientific evaluation.

First, IOs can use their agenda-setting power to increase the salience of certain technologies. Bisbee et al. (2019) show that, as an international assessment mechanism of government performance, global performance indicators (GPIs) induced governments to move the investment in social developments that are not calculated in GPIs to targets that are measured in GPIs. The same logic may apply to firms' investment decisions. Once IOs categorize certain technologies as of higher priority than other related technologies, profit-driven actors can expect a higher return from the investment and may have incentives to channel investment in other technologies to the more salient ones.

Second, IOs can design the entry barriers in the scientific evaluation process to reduce the cost of investment in certain technologies. By simplifying the evaluation procedure, expediting the evaluation process, and lowering the evaluation threshold for certain technologies, IOs can reduce the marginal costs of investing in these technologies for firms, which increases firms' incentives to invest in these areas.

Third, IOs can use their networks with other IOs and non-governmental organizations (NGOs) to connect the new technology to a new market. Such created demand can increase the expected return on investment in these technologies and increases the marginal costs that firms are willing to bear.

By privileging certain technologies over others through the mechanisms of salience, entry barriers, and marker access, IOs can use scientific evaluation to channel profit-driven actors' investment into areas that contribute to IOs' own institutional goals. This process

is consistent with the conventional understanding of IOs as an epistemic community (Haas, 1992). Rather than focusing on the mechanism of norms creation (Haas, 1989), our argument emphasizes the market implications of scientific evaluation, which empowers IOs as an epsitemic community.[1]

3 Vaccine Endorsement by the WHO

To empirically examine this argument, we focus on the case of vaccine endorsement by the WHO, which is a hard case to test the market mechanism of scientific evaluation by IOs. Due to the disease disparity between rich and poor countries, resources allocated to health research focus more on diseases concentrated in rich countries (Adam et al., 2023), leading to an underinvestment in vaccines targetting diseases concentrated in poor countries. Due to the lack of a functioning market mechanim, pharmaceutical firms, the main producers of vaccine technologies, are not incentivized to invest in vaccine targetting poor countries. Can the WHO motivate these firms to change their investment in different medical technologies?

Before connecting this case to the argument on scientific evaluation by IOs, this section lays out the WHO's relationship with science and describes the vaccine prequalification programme at the WHO.

3.1 World Health Organization and Science

The WHO is a specialized agency of the United Nations (UN) in charge of promoting international public health. Prior to the creation of the WHO, the first effort of international coopration on global health started from the International Sanitary Conference in 1851. The priorities of the International Sanitary Conference in the late nineteenth and early twentieth centuries focused on preventing the spread of a limited list of diseases—cholera, plagure, and yellow fever—from Asia and the Middle East to Europe and North America (Fidler,

[1] Appendix A shows a bayesion persuasion model to illustrate this intuition.

2005). The establishment of the WHO expanded the narrow scope in this old regime and embraced new goals, policy orientation, and strategy to address global health. More specifically, the WHO embraced the goal of Health for All, which covers not only the eradication and containment of infectious diseases, but also the improvement of overall health outcomes, especially in the developing world. Meanwhile, the WHO's policy orientation transformed from old regimes' focus on balancing economic interests of great powers with health risks to the pure focus on improving health outcomes through disease eradicaton and universal primary health care. Lastly, the WHO's strategy compared to the old regime involves active application and dissemination of scientific advancements, such as antibiotics and vaccines.

The WHO focuses on three aspects to guide, develop, and deliver health policies based on scientific evidence. The first is to set the agenda to guide the research focus to gaps and priorities that are responsive to local contexts. The second is to evaluate the quality of new scientific advancements by developing and disseminating the appropriate norms and standards for practice. The last is to translate the latest data, research, and evidence into real-world adoption. Therefore, the WHO plays a critical role in connecting the scientific community to real-world practitioners for the promotion of health for all populations around the world.

3.2 Vaccine Prequalification at the WHO

We focus on one specific case of the evaluation of scientific advancements: vaccine prequalification. Vaccines are one of the most successful and cost-effective health interventions (World Health Organization, 2009). Different from chemical pharmaceuticals, vaccines are biological products and are derived from living organisms. Due to the inherent variability of living organisms, vaccines could be damaged from the contamination of materials or changing environments. Constant qualitiy control and assessment are necessary to ensure the safety and efficacy of vaccine products.

As a result of constant demand for quality control by the United Nations Children's Fund

(UNICEF) and other UN procurement agencies, the vaccines prequalification programme was established in 1987. The programme started as a modest project which involved the testing of vaccine lots, review of summary lot protocols, and the inspection of manufacturing sites. As the demand, diversity, and complexity of vaccine products submitted for prequalification continued to grow, the WHO revised its prequalification procedure. Since 2002, the WHO has required the national regulatory authority (NRA) of the vaccine producing country to be functional—defined as the establishement of appropriate capacity for vaccine regulation—as a prerequisite for accepting submissions of vaccine prequalification by manufacturers from that country. This requirement has a great impact on strengthening vaccine regulation capacity in developing countries. In 2012, in reponse to the increased volume and cost of new vaccines, the WHO developed a streamlined prequalification procedure to reduce the timeline and resources for assessment. For example, the assessment reports by certain NRAs are recognized to avoid duplicative regulatory efforts.[2]

In addition to quality control, the WHO also collaborates with the UNICEF and Global Alliance for Vaccines and Immunization (GAVI) to predict, maintain, and create the market for vaccines. The vaccine market is small and concentrated from both the supply and demand perspective. More specifically, on the supply side, manufacturers of vaccines are mainly located in developed countries. On the demand side, however, many diseases are concentrated in low- and middle-income countries (LMICs). While vaccine sales to high-income countries generate more revenue, sales to LMICs are of much larger volume. Due to the geographic mismatch in the demand and supply of vaccines, it is challenging for manufacturers to predict which vaccine product to prioritize. Moreover, given that each vaccine product—even for the same type of disease—has its specificities, individual vaccines or vaccine types have their own individual markets, making the prediction of the pricing and procurement a complex task. Given the complex nature of vaccine market, the WHO's function of connecting vaccine manufacturers with the procurement agencies and donors in these agencies plays a

[2]The recognizaed NRAs include Australia, Belgium, Canada, France, Italy, the United States, and the European Medicines Agency.

critical role in ensuring a healthy vaccine market.

3.3 Procedure of Vaccine Prequalication

For a vaccine product to be eligible for prequalification, the vaccine has to be on the Vaccines Prequalification Priority List,[3] which categorizes the priority of vaccines that are anticipated to be available for supply. The list is made every two years by the WHO in consultation with the UNICEF and the Revolving Fund of the Pan American Health Organization, a mechanism that provide technical suport to national immunization programs through overcoming the barriers of price and access. Four criteria determine the priority of a vaccine: market demand, programmatic needs of the WHO, recommendation by the WHO's Strategic Advisory Group of Experts on immunization (SAGE), and supply security due to shortage.

To start the prequalification process, manufacturers have to initiating the process by submitting an application to the WHO. However, for a manufacturer to be eligible, the corresponding NRA of the manufacturer must be classified as a functional NRA or WHO-listed authority operating at maturity level 3. This is to ensure the regulatory oversight of the product. After the submission, the WHO will screen the application based on the programmatic suitability (World Health Organization, 2014), which evaluates the characteristics of the vaccine candidate, such as heat stability, presentation, labeling, and shipping conditions. Only when the vaccine candidate is compliant with the complusory characteristics can the product start the prequalification assessment.[4] The assessment includes a scientific evaluation of evidence, sample testing, and inspection of the manufacturing site. Once a vaccine product is considered to meet all the requirements, it will be included in the WHO List of Prequalified Vaccines.[5]

After a vaccine product passes the prequalification requirements, there is an annual eval-

[3]Website: https://extranet.who.int/prequal/vaccines/vaccines-eligible-who-prequalification

[4]There are two categories of characteristics: mandatory and critical characteristics. Both categories are compulsory, but if a product deviates from the critical characteristics, the screening procedure will go through a review process involving the manufacturer and procurement agencies to determine whether to accept the application.

[5]Website: https://extranet.who.int/prequal/vaccines/prequalified-vaccines

uation to ensure the quality and continued compliance with the required standards of the product. If a product fails to meet the post-prequalification testing and reporting requirements, the WHO can withdraw the product from its list of prequalified vaccines. Manufacturer can also withdraw their product from the list due to discontinued production or commercialization.

4 Hypotheses

As a case of scientific evaluation by IOs, the vaccine prequalification programme at the WHO allows us to empirically examine whether and how the WHO can use scientific evaluation to achieve its institutional goals.

As is discussed, the WHO's institutional goal has transformed since its inception from the management of the disruption of global health emergencies on global economy to the improvement of health outcomes of all human beings. This transformation suggests that the WHO's vaccine prequalication programme aims to correct for the unequal distribution of resources on health research between rich and poor countries. Specifically, the WHO will try to channel pharmaceutical firms' investment into vaccine technologies targetting disease concentrated in low-income countries. Therefore, the vaccine prequalification programme should reflect the WHO's attempt to privilege vaccines targetting the need of low-income countries (World Health Organization, 2023). The following three hypotheses examines the three mechanisms of how scientific evaluation by IOs can change the behavior of market-oriented actors.

Hypothesis 1. ***Agenda Setting*** *The WHO's evaluation prioritizes vaccines targetting diseases with more disparity.*

Hypothesis 2. ***Entry Barriers*** *The WHO sets lower entry barriers in the evaluation process for vaccines targetting diseases with more disparity.*

Hypothesis 3. ***Market Access*** *Vaccines targetting diseases with more disparity are more likely to be procured by other UN agencies.*

To examine the effect of the WHO's vaccine prequalification programme on market-oriented actors' behaviors, the following hypothesis lays out the theoretical prediction of where the increased vaccine investment is most likely.

Hypothesis 4. ***Effect of Vaccine Endorsement*** *The privileged vaccines in the WHO's prequalification programme should have more investment by pharmaceutical firms.*

5 Data

5.1 Disease Inequality

Our theory suggests that the WHO should prioritize vaccines based on whether the diseases they target are unequally distributed in developing countries. For empirical examination of the theory, we start by constructing a sample of diseases from the Disease Outbreak News (DONs) by WHO. The program publishes timely reports of confirmed or potential public health events from local governments. We then construct an inequality index for each disease in a given year based on the number of countries reported a threat or the population of threatened countries. The index is measured using the Gini index approach and ranges between 0 and 1. We construct the index by replacing the income distribution of traditional Gini coefficient with the distribution of affected population. When a disease receive an inequality index of 0, it suggests that this disease is equally distributed across all countries. Diseases that are concentrated in a small number of countries, such as Ebola, receive an inequality index closer to 1.

When constructing this index, we assume that countries that did not report an outbreak are not affected by the disease in a given year after the first reporting. An implicit assumption for using DONs data is that governments always choose to report the outbreaks.

Although governments have incentives to hide outbreaks, we believe that under-reporting does not significantly affect our results for two reasons. First of all, The International Health Regulations (IHR) reform in 2005 authorized the WHO to act on behalf of local governments using non-governmental sources of information when governments do not cooperate. Hence under-reporting should not significantly reduce the number of diseases reported. Secondly, one may be concerned that a disease receives a higher inequality score when governments hide the outbreaks. Since our theory focuses on how the WHO prioritizes certain diseases, the inequality measurement should capture the level of inequality perceived by the WHO, which is exactly what the DONs data reflect. Hence outbreaks undisclosed by governments should not affect the WHO priority in the first place and thus should not affect the downstream firm behaviors.

5.2 Vaccine Endorsement

The empirical implication of our theory suggests that we should observe a positive relationship between inequality index and priority status, meaning that WHO is more likely to prioritize the approval of vaccines for unequally distributed diseases to facilitate investments in under-invested areas. Ideally we would like to obtain a full list of vaccines submitted for pre-qualification and examine whether vaccines targeting unequally distributed diseases are more likely to be pre-qualified. However, WHO does not publish the universe of vaccines for which firms have submitted a pre-qualification application. Estimates based on pre-qualification results may capture application instead of WHO priority. Hence we construct two measurements for WHO priorities at the disease level. The first measurement is a priority index based on the list of prioritized vaccines that WHO announces every two years. The list specifies four levels of priority: high, medium, low and no priority. We assign scores to each diseases depending on the number of vaccines listed in each priority category targeting such disease. We assign three points for each high-priority vaccine, two points for each medium-priority vaccine, one point for each low-priority vaccine and zero for no

priority. Diseases for which no vaccine is listed receive zero. The list of prioritization is set for every two years. The preliminary data source we adopt is cross-sectional data from the 2018-2020 time period. We construct another measurement of priority using the number vaccines pre-qualified by WHO with the aforementioned caveat. This measurement captures the number of vaccines pre-qualified for a disease in a given year. The implication here is that the WHO pre-qualifies more vaccines when it prioritizes a certain disease.

5.3 Demand in Vaccines for Prioritized Diseases

The WHO also prioritizes unequally distributed diseases by facilitating market access. When vaccines for certain diseases are prioritized, firms, especially development agencies, expect increasing demand for such vaccines, which further encourages investments. Empirically we should expect to observe a positive relationship between disease inequality and market demand. In the preliminary results, we measure market demand by vaccine shipment data reported by GAVI. Data collection for GAVI shipment is an ongoing process. The current data source in the preliminary results covers shipments in the 2016-2020 time period.

5.4 Investment in Vaccine Research and Development (R&D)

Our theory also predicts that the WHO may facilitate further investments by prioritizing the endorsement of vaccines targeting unequally distributed diseases. It implies that firm investments should be positively associated with WHO prioritization. Due to lack of information on firm investments at the vaccine level, we measure the level of development efforts by the number of clinical trials registered at the disease level. The International Clinical Trials Registry Platform (ICTRP) compiles registration records submitted by a network of primary registries that meet specific criteria for content and quality. These registries are mainly official registries enforced by governments such as Australian New Zealand Clinical Trials Registry (ANZCTR) and EU Clinical Trials Register (EU-CTR). Over half of the registries are updated within a year of our latest data scraping. We identify clinical trials

registered under disease topics included in our disease sample and compute the number of registered trials as a measurement for firm efforts associated with each disease. The measurement can be coarse as topics do not exactly match diseases and include overlapping categories. Moving forward, we plan to further identify trials with diseases using text-based approach on the registration descriptions.

Table 1: Summary Statistics

Variable	Min.	Mean	Max.	N	N. Disease
Year	1996		2020		
Inequality (country)	0	0.24	0.99	1415	66
Inequality (population)	0	0.24	0.99	1415	66
Vaccine prequalified	0	0.05	1	1758	66
Priority Index	0	1.0	13	1758	66
Number of trials	0	29.0	5613	1758	66
GAVI Shipment (Doses in Millions)	0	72.9	207.8	119	13

6 Results

We examine the relationship between disease inequality and WHO priority using the following specification:

$$Priority_{it} = \alpha_1 + \beta_1 Inequality_{it} + X'\boldsymbol{\gamma_1} + \epsilon_1$$

where i denotes disease and j denotes year. *Priority* refers to a set of outcomes that measure WHO priority such as the priority index and whether any vaccines are pre-qualified. We expect inequality to be positively correlated with both measurements of priority. We then estimate the relationship between WHO priority and firm efforts with the following specification:

$$Investment_{it} = \alpha_2 + \beta_2 Priority_{it} + X'\boldsymbol{\gamma_2} + \epsilon_2$$

where *Investment* is measured by the number of registered trials in RCTRP. We also

expect a positive relationship between these two measures. Table 2 shows preliminary estimates for the first specification. We find a significantly positive relationship between both inequality measurements and priority index, which lends support for our hypothesis that the WHO prioritizes unequally distributed diseases. The relationship between inequality index and vaccine pre-qualification is positive but weakly significant. Note that as discussed before, the pre-qualification measurement captures not only the WHO prioritization but also submission for approval, which may introduce noise into the estimation. But the direction of the coefficient estimates are consistent with our hypothesis. It is important to note that the we only provide suggestive evidence of correlation instead of identifying a causal relationship. While the relationships between inequality and GAVI shipments are insignificant, they are also in the expected direction. The large standard errors are likely driven by the fact that GAVI shipment data only cover the period of 2016-2020. We expect the pattern to be more clear once we incorporate more years of data.

Table 2: Preliminary Empirical Results - Disease Inequality

	Dependent variable:							
	Priority Index		Any Vacc. Prequal.		# of Vaccines Prequal.		GAVI Procurement	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Inequality (country)	1.119***		0.025		0.002		2.922	
	(0.176)		(0.015)		(0.098)		(10.886)	
Inequality (pop.)		1.075***		0.027*		0.007		3.067
		(0.173)		(0.015)		(0.097)		(10.640)
Year Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,415	1,415	1,415	1,415	1,415	1,415	119	119
R^2	0.033	0.032	0.089	0.090	0.147	0.147	0.366	0.366
Adjusted R^2	0.015	0.014	0.073	0.073	0.132	0.132	0.326	0.326
Note:								*p<0.1; **p<0.05; ***p<0.01

We also observe strongly positive relationship between priority and firm efforts as shown in Table 3, which suggests that firms do follow the direction of WHO priority. The relationship holds across three measurements of WHO priority: priority index and two measurements constructed based on vaccine pre-qualification. One potential concern is that the relation-

ship could be driven by the fact that both WHO and firms prioritize disease with higher burdens. Moving forward, we plan to incorporate disease burden data from Global Disease Burden initiative, which provides information on years of lives lost by different causes across countries. The relationship between inequality and WHO priority is more informative as unequally distributed diseases may not have higher global burden. We also present the coefficient estimates on the relationship between disease inequality and firm investments. Estimates presented in columns (4)-(5) in Table 3 suggest that firm efforts are not directly affected by disease inequality but through WHO endorsement.

Table 3: Preliminary Empirical Results - Clinical Trials

	Dependent variable:				
	Number of Trials				
	(1)	(2)	(3)	(4)	(5)
Priority Index	349.681**				
	(167.161)				
Any Vacc. Prequal.		98.404***			
		(18.797)			
# of Vacc. Prequal.			7.818***		
			(3.001)		
Inequality (country)				16.534	
				(11.723)	
Inequality (pop.)					16.056
					(11.505)
Constant	455.472				
	(420.681)				
Year Fixed effects	Yes	Yes	Yes	Yes	No
Observations	66	1,758	1,758	1,415	1,415
R^2	0.064	0.039	0.027	0.023	0.023
Adjusted R^2	0.049	0.025	0.013	0.006	0.006
Note:					*p<0.1; **p<0.05; ***p<0.01

Our results suggest that WHO prioritizes diseases that are concentrated in developing economies. We plan to conduct robustness checks for correlation between inequality and disease burden when disease burden data is fully cleaned. Another potential bias is that WHO may selectively report outbreaks that it prioritizes. As we assign zero to inequality

index if a disease is not reported in any country in a given year, WHO prioritized diseases are more likely to have a non-zero inequality index. This would only be a concern if our sample of diseases is collected from outside of WHO. Since our sample of diseases comes from DONs, all reported diseases should be equality prioritized and have the same chance to be reported.

7 Conclusion

Delegating scientific evaluation to IOs increases the efficiency of scientific advancement and implementation yet also introduces potential favoritism. The production of scientific information in IOs remains relatively under-studied. This paper proposes a developmental model of scientific information production. We hypothesize that IOs prioritizes scientific advancements unequally benefiting developing regions and provide empirical evidence in support of the hypothesis using WHO's vaccine pre-qualification program. We further show that WHO's prioritization and endorsement facilitates firm investments in otherwise under-invested areas.

Understanding the production of scientific information in IOs bears important implications. First of all, centralization of scientific information evaluation reduces governments' costs in capacity enhancement and administrative tasks but at the expense of a less transparent process. Governments may not trust the information disseminated by IOs when they believe it is produced with political bias. This paper suggests that developmental priority is an important driver behind IOs policy-making process despite the existence political factors suggested by previous studies. We also emphasize that in addition to directing government behaviors, IOs' policies can also exert influence through affecting private sector behaviors.

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A A Bayesian Persuasion Model of Vaccine Endorsement

The intuition of the model follows the bayesian persuasion framework by Kamenica and Gentzkow (2011).

A.1 Assumption

Senders' commitment power: The endorsement process at the WHO follows a random draw process. One interpretation of this assumption is that the board of scientific evaluation is composed of experts with private types. With the rotation of experts, the decision-making process of scientific evaluation can follow a probabilitic draw.

A.2 Model: Actors

- Firm F
- The WHO A (sender)
- Government G (receiver)

A.3 Model: Sequence

1. F chooses its vaccine investment $\kappa \in [0, 1]$
2. A chooses a vaccine endorsement strategy $\pi(\omega)$
    - ω: whether a vaccine is effective
    - s: whether the WHO endorses
    - Always endorse if effective: $Pr(s = 1|\omega = 1) = 1$, $Pr(s = 0|\omega = 1) = 0$
    - Sometimes endorse if not effective: $Pr(s = 1|\omega = 0) = \beta$, $Pr(s = 0|\omega = 0) = 1-\beta$
3. G observes $\pi(\omega)$
4. Nature chooses $\omega \in \{0, 1\}$ based on $\mu_0 = Pr(\omega = 1) = \kappa$
5. G observes $s \in \{0, 1\}$, which is realized based on $\pi(\omega)$
6. G decides whether to buy the vaccine $a \in \{0, 1\}$

A.4 Model: Payoffs

- A wants effective vaccine

$$u = U_A = \kappa$$

- G wants to buy effective vaccines

$$v = U_G = \begin{cases} \omega & \text{if } a = 1 \\ 1 - \omega & \text{if } a = 0 \end{cases}$$

- F aims to maximize its profits

$$U_F = \lambda a - \frac{(\kappa - b)^2}{2\theta}$$

  - λ: vaccine demand
  - θ: production technology
  - b: external grant/government subsidies

A.5 Consider the case with only A and G

G's posterior belief:

$$Pr(\omega = 1|s = 0) = \frac{Pr(s = 0|\omega = 1)Pr(\omega = 1)}{Pr(s = 0|\omega = 1)Pr(\omega = 1) + Pr(s = 0|\omega = 0)Pr(\omega = 0)} = 0$$

$$\begin{aligned} Pr(\omega = 1|s = 1) &= \frac{Pr(s = 1|\omega = 1)Pr(\omega = 1)}{Pr(s = 1|\omega = 1)Pr(\omega = 1) + Pr(s = 1|\omega = 0)Pr(\omega = 0)} \\ &= \frac{1 \times \kappa}{1 \times \kappa + \beta(1 - \kappa)} \end{aligned}$$

A manipulates the posteriors s.t.

$$Pr(\omega = 1|s = 1) = \frac{1}{2}, \text{ and } a(s = 1) = 1 \Rightarrow \beta = \frac{\kappa}{1 - \kappa}$$

A's endorsement strategy $\pi(\omega)$:

- $Pr(s = 1|\omega = 1) = 1$, $Pr(s = 0|\omega = 1) = 0$
- $Pr(s = 1|\omega = 0) = \frac{\kappa}{1 - \kappa}$, $Pr(s = 0|\omega = 0) = \frac{1 - 2\kappa}{1 - \kappa}$

G's expected purchase ex ante: $E_\mu(a) = \kappa \times 1 + (1 - \kappa)\frac{\kappa}{1 - \kappa} = 2\kappa > \kappa = \mu_0$

A.6 Now consider the case with F, A, and G

F's optimization problem:

$$\begin{aligned} E_\mu(U_F) =& \lambda E_\mu(a) - \frac{(\kappa - b)^2}{2\theta} \\ =& 2\kappa\lambda - \frac{(\kappa - b)^2}{2\theta} \end{aligned}$$

F.O.C.

$$\kappa^* = 2\lambda\theta + b$$

Assume that $b \leq 1 - 2\lambda\theta$:
Vaccine demand ↑, production tech ↑, government subsidy ↑⇒ κ^* ↑

- Fast Covid vaccine
- Slow Ebola vaccine

A's endorsement strategy $\pi(\omega)$:

- $Pr(s = 1|\omega = 1) = 1$, $Pr(s = 0|\omega = 1) = 0$
- $Pr(s = 1|\omega = 0) = \beta = \dfrac{2\lambda\theta + b}{1 - 2\lambda\theta - b}$, $Pr(s = 0|\omega = 0) = \dfrac{1 - 4\lambda\theta - 2b}{1 - 2\lambda\theta - b}$
  - $\dfrac{\partial\beta}{\partial\lambda} = -\dfrac{2\theta}{(1 - 2\lambda\theta - b)^2} < 0$
  - $\dfrac{\partial\beta}{\partial\theta} = -\dfrac{2\lambda}{(1 - 2\lambda\theta - b)^2} < 0$
  - $\dfrac{\partial\beta}{\partial b} = -\dfrac{2}{1 - 2\lambda\theta - b} < 0$

Vaccine demand ↑, production tech ↑, government subsidy ↑⇒ over-endorsement ↓

A.7 Equilibrium

Equilibrium concept: weak Perfect Bayesian Equilibrium

- F invests $\kappa^* = 2\lambda\theta + b$
- A's endorsement strategy $\pi(\omega)$:
  - $Pr(s = 1|\omega = 1) = 1$
  - $Pr(s = 1|\omega = 0) = \dfrac{2\lambda\theta + b}{1 - 2\lambda\theta - b}$

- G's purchase strategy $a^* = s$
- G's posterior belief μ:
  - $Pr(\omega = 1|s = 1) = 0.5$
  - $Pr(\omega = 1|s = 0) = 0$