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Barriers to child vaccination: The role of international sanctions

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ABSTRACT

International sanctions are often imposed with the aim of influencing the political behavior of target states, but they may have unintended consequences on public health. This study empirically examines the impact of international sanctions on child immunization rates in developing countries. Utilizing panel data from 76 developing countries between 2000 and 2019, the analysis explores how different types of sanctions, including those from the US, EU, and UN, as well as economic and unilateral sanctions, affect the immunization rates for DPT, Hepatitis B, and Measles vaccines. The findings indicate that sanctions, particularly those imposed by the US and EU, significantly reduce vaccination rates, with economic and unilateral sanctions showing the most substantial negative impact. Additionally, the study highlights the moderating role of health spending, revealing that increased healthcare investment can mitigate some of the adverse effects of sanctions. Poorer developing countries are disproportionately affected compared to their more affluent counterparts. The results underscore the need for policymakers to consider the broader public health implications of sanctions and for international efforts to ensure that essential medical resources remain accessible in sanctioned countries. This study contributes to the literature by providing comprehensive empirical evidence on the detrimental effects of international sanctions on child immunization, advocating for a balanced approach that protects public health while achieving geopolitical objectives.

1. Introduction and literature review

1.1. Background and research significance

The global community recognizes the critical issue of children's vulnerability to infectious diseases due to inadequate immunization. In response, intergovernmental and non-governmental organizations have undertaken significant efforts to address this problem, particularly in developing countries. The World Health Assembly (WHA), for example, launched the Global Alliance for Vaccines and Immunization (GAVI) to provide financial assistance and facilitate vaccine distribution in low-income countries (Bustreo et al., 2015). GAVI has expanded child vaccination coverage and promoted the adoption of WHO-recommended vaccines in 73 low-income countries, ensuring vaccines reach vulnerable populations (Bustreo et al., 2015).

Child immunization is crucial for protecting children from preventable diseases such as measles, diphtheria, hepatitis B, and polio. Immunization also contributes to herd immunity, which reduces the spread of infectious diseases that can cause severe health complications or death (UNICEF, 2024; World Health Organization, 2023). Moreover, immunization plays a vital role in sustainable development and health equity by ensuring that all children, regardless of socioeconomic status, have access to life-saving vaccines. This effort reduces health disparities, promotes a healthier future workforce, and contributes to economic stability and growth. Vaccination programs also prevent disease outbreaks, helping maintain public health infrastructure and supporting long-term community resilience.

Despite progress in global immunization and reductions in mortality rates through improved access to vaccines (Duclos et al., 2009), over five million children under five still die annually from preventable diseases due to limited access to quality healthcare, including vaccines (Save the Children, 2024). Addressing these gaps requires enhanced global cooperation and continued investment in immunization programs. Immunizing children not only saves lives but also reduces the burden on

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healthcare systems, allowing for more efficient resource allocation. Healthy children are more likely to attend school and become productive adults, contributing to their communities' social and economic development. Thus, investing in immunization secures a healthier, more equitable future for all (Ducharme et al., 2023).

1.2. Literature review

Several barriers hinder children's access to vaccines, including parental distrust of vaccines (Jelle et al., 2023), lack of knowledge (Domgue et al., 2020), misinformation (Wilson & Wiysonge, 2020), vaccine unaffordability (Khan & Ahmad, 2017), poverty (Niccolai et al., 2011), and limited regional availability, particularly in remote areas (Metcalf et al., 2015). However, external political pressures, particularly international sanctions, also significantly impact vaccine access.

International sanctions, imposed by intergovernmental organizations or state actors, aim to pressure or compel changes in political behavior. These measures often have far-reaching effects, leading to over-compliance or de-risking, where nation-states and industry sectors avoid providing services to targeted countries due to fears of economic or political repercussions (Blanchet et al., 2021). Such dynamics can severely restrict a country's ability to access essential medical supplies, including vaccines.

Research increasingly recognizes the wide-ranging and often devastating impacts of sanctions on target states, whether intentional or not (Early & Peksen, 2022). Studies have documented various socio-economic, environmental, and political consequences of sanctions, including increased poverty (Moteng et al., 2023), food insecurity (Mohammadi-Nasrabadi et al., 2023), hindered economic development (Gutmann et al., 2023), political instability (Peksen, 2021), human rights violations (Peksen, 2009), reduced innovation (Fu et al., 2023), and implications for climate change mitigation (Ko et al., 2024b, Leung, et al., 2024). In public health, sanctions have led to increased mortality (Daponte & Garfield, 2000), reduced life expectancy (Gutmann et al., 2021), higher mortality rates from diseases (Miromanova, 2024), elevated child mortality rates (Peksen, 2011), constraints on government healthcare spending (Al-Mustanyir, 2024), and limited access to non-communicable medicines (Kheirandish et al., 2018).

1.3. Literature gap and hypothesis development

Despite extensive research on the broader impacts of international sanctions, few studies specifically examine their effects on children's vaccine access. Existing studies primarily focus on countries like Iran, Iraq, or Haiti, which have faced intense sanctions. For example, Setayesh and Mackey (2016) found that strict U.S. export controls on Iran, including Non-EAR99 categories, hindered the export of vaccines and medical resources, exacerbating vaccine shortages and impacting healthcare delivery. Similarly, Khankeh et al. (2021) highlighted that international sanctions strained Iran's healthcare system and hindered access to COVID-19 vaccines, contributing to initially low vaccination rates.

In Iraq, international sanctions following the Gulf War caused an economic crisis that severely reduced the government's budget. This financial strain led to a 90% reduction in the health budget, resulting in the cancellation of many infectious disease control programs, including critical immunization services (Østby et al., 2021). Consequently, Iraqi children experienced a significant reduction in immunization rates against Hepatitis B Virus (HBV), leading to a widespread prevalence of HBV among children during the years of intense sanctions (Ali, 2004). In Haiti, Gibbons (2002) reported that the multilateral embargo in the 1990s led to an economic downturn and resource shortages, including fuel, which caused issues with vaccine refrigeration and a significant drop in children's immunization coverage from 40% in 1991 to 12% in 1993.

These cases illustrate two primary pathways through which international sanctions undermine child immunization rates. First, sanctions can cripple a nation's economy, leading to severe budgetary constraints on the healthcare system. This financial strain can result in the scaling down or cancellation of immunization programs, as seen in Iraq. Second, sanctions can dissuade financial and healthcare sectors from engaging with sanctioned countries, reducing vaccine availability and impeding the immunization of children against infectious diseases.

While existing literature provides valuable insights into the adverse effects of international sanctions on child vaccination in targeted countries, empirical research is needed to explore whether sanctions broadly impede global immunization efforts against communicable diseases. This study seeks to fill this gap by empirically examining the impact of international sanctions on child immunization rates, focusing on four key vaccines: DPT (Diphtheria, Pertussis, and Tetanus), Hepatitis B, Measles, and Polio. The following hypotheses guide this research.

- **H1:** International sanctions reduce the Children's DPT Immunization Rate in Target Countries.
- **H2:** International sanctions reduce the Children's Hepatitis B Immunization Rate in Target Countries.
- **H3:** International sanctions reduce the Children's Measles Immunization Rate in Target Countries.
- **H4:** International sanctions reduce the Children's Polio Immunization Rate in Target Countries.

Different types of international sanctions may have varying effects on targeted countries. Fu and Chang (2024) observed that sanctions imposed by the US and EU on green innovation tend to have more adverse effects on target countries, while UN or multilateral sanctions may not produce the same outcomes. Some studies suggest that unilateral sanctions exert a stronger impact on target countries (e.g., Chen et al., 2019), while others argue that plurilateral sanctions have a more detrimental effect compared to unilateral sanctions (e.g., Fu & Chang, 2024; Fu et al., 2023). Additionally, research highlights that sanctions targeting the national economy of the target countries (e.g., Chen et al., 2019; Fu et al., 2020; Wang et al., 2019) and high-intensity sanctions tend to have more adverse effects (e.g., Moteng et al., 2023; Wang et al., 2019). The final hypothesis reflects these considerations.

- **H5:** Different types of international sanctions have varying effects on Children's Immunization Rates across all vaccine types.

2. Methodology

2.1. Focus of the study

This study examines the impact of international sanctions on child immunization rates in developing countries, utilizing panel data from 2000 to 2019. The analysis focuses on 76 developing nations that were affected by international sanctions during this period. The timeframe was selected based on the availability of comprehensive datasets, ensuring the inclusion of countries classified as developing according to the criteria established by Nygen et al. (2020). This classification is consistent with prior studies, including those by Ko et al. (Forthcoming) and Biglaiser and McGauvran (2022).

The emphasis on developing countries stems from the pattern of Western developed nations frequently targeting these nations with sanctions, often driven by motives such as economic protectionism, human rights allegations, or geopolitical strategies. Developing countries, with their typically limited financial resources, are more vulnerable to the adverse effects of international sanctions (Chen et al., 2019). Therefore, the decision to include only the 76 sanctioned developing countries, rather than all developing nations, serves to maintain the integrity of the statistical analysis by reducing potential noise that non-sanctioned countries might introduce.

The study period begins in 2000 to align with available data on child

immunization rates, essential for analyzing the impact of sanctions on these health outcomes. However, it also includes developing countries sanctioned as early as 1990 to capture significant geopolitical shifts in the post-Cold War era, marked by U.S. unipolarity and the EU's rise as a global actor. Only five countries—Algeria, Jordan, Malawi, South Africa, and Zambia—had sanctions predating 2000 with vaccination data available, ensuring a broader analysis. This approach enables an assessment of whether international sanctions directly affected childhood vaccination rates or if other factors influenced the observed trends. The study period concludes in 2019 due to the dataset's limitation, which does not extend beyond that year for international sanctions variables. Additionally, ten countries—Burma, China, Cuba, the Democratic Republic of Congo, Iran, Libya, North Korea, Serbia, Somalia, Syria, and Sudan—remained under continuous sanctions from 1990 to 2019, providing valuable insights into the long-term effects of sanctions.

2.2. Key variables and covariates

The study utilized international sanctions variables sourced from the German Institute of Global and Area Studies (GIGA) Sanction dataset by Von Soest and Portela (2012) and the Global Sanctions Data Base (GSDB) by Felbermayr et al. (2020). These datasets provide detailed information on the sanctions imposed on target countries, including the

Table 1
Descriptive statistics.

Variable	Definition	Mean	SD	Min	Max	Source
DPT Immunization (logged)	Percentage of children aged 12–23 months immunized against DPT before turning 12 months old or before the survey date. A single dose of the vaccine constitutes adequate immunization.	4.3531	0.2808	2.9444	4.5951	World Bank (2023)
Hepatitis B Immunization (logged)	Percentage of children aged 12–23 months immunized against Hepatitis B before turning 12 months old or before the survey date. Adequate immunization requires three doses of the vaccine.	4.3709	0.3095	1.3863	4.5951	World Bank (2023)
Measles Immunization (logged)	Percentage of children aged 12–23 months immunized against Measles before turning 12 months old or before the survey date. Adequate immunization requires one dose of the vaccine.	4.3474	0.2674	2.7726	4.5951	World Bank (2023)
Polio Immunization (logged)	Percentage of children aged 12–23 months immunized against Polio before turning 12 months old or before the survey date. Adequate immunization requires three doses of the vaccine.	4.3683	0.2489	3.1355	4.5951	World Bank (2023)
US Sanctions	Binary variable indicating whether the US imposed sanctions on a country in a specific year (1 = Yes, 0 = No).	0.3164	0.4652	0	1	Felbermayr et al. (2020); Von Soest and Portela (2012)
EU Sanctions	Binary variable indicating whether the EU imposed sanctions on a country in a specific year (1 = Yes, 0 = No).	0.2789	0.4486	0	1	Felbermayr et al. (2020); Von Soest and Portela (2012)
UN Sanctions	Binary variable indicating whether the UN imposed sanctions on a country in a specific year (1 = Yes, 0 = No).	0.1322	0.3389	0	1	Felbermayr et al. (2020); Von Soest and Portela (2012)
Intensity	Intensity of international sanctions, ranked from 0 (no sanctions) to 5 (highest intensity, e.g., embargo).	1.2112	1.6177	0	5	Felbermayr et al. (2020); Von Soest and Portela (2012)
Economic Sanctions	Binary variable indicating whether a country faced economic sanctions in a specific year (1 = Yes, 0 = No).	0.3316	0.4709	0	1	Felbermayr et al. (2020); Von Soest and Portela (2012)
Unilateral Sanctions	Binary variable indicating whether sanctions were imposed solely by either the EU or the US in a specific year (1 = Yes, 0 = No).	0.1638	0.3702	0	1	Felbermayr et al. (2020); Von Soest and Portela (2012)
Plurilateral Sanctions	Binary variable indicating whether sanctions were imposed simultaneously by both the EU and the US in a specific year (1 = Yes, 0 = No).	0.1171	0.3217	0	1	Felbermayr et al. (2020); Von Soest and Portela (2012)
GDP per capita (logged)	Log-transformed GDP per capita as a measure of a country's economic development for a specific year.	8.4780	0.9620	6.5381	10.4826	World Bank (2023)
Population (logged)	Log-transformed total population (in millions), including all residents regardless of legal status or citizenship.	2.6525	1.4345	−1.4271	7.2497	World Bank (2023)
Urbanization (logged)	Log-transformed percentage of the urban population as defined by national statistical authorities.	3.7597	0.4625	2.1102	4.5131	World Bank (2023)
Dependency Ratio (logged)	Log-transformed age dependency ratio, defined as the ratio of dependents (under 15 or over 64) to the working-age population (15–64).	4.2177	0.2984	3.6136	4.6955	World Bank (2023)
Globalization (logged)	Log-transformed composite index of globalization, capturing economic, social, and political integration.	3.9257	0.2423	3.1987	4.4005	Dreher (2006)
Natural Resources GDP % (logged)	Log-transformed contribution of natural resource rents as a percentage of national GDP.	1.6402	1.3232	−3.2189	4.4840	World Bank (2023)
Democracy	V-DEM index of democracy, scored from 0 (no democracy) to 5 (high democracy), assessing participatory, egalitarian, electoral, liberal, and deliberative dimensions.	1.3817	0.7918	0.1630	3.5700	Coppedge et al. (2019)
Foreign Aid Per capita (logged)	Log-transformed foreign aid received per capita in 2022 US dollars, including grants and loans from other countries, intergovernmental organizations, and agencies.	2.9077	2.5232	−6.9078	6.6445	World Bank (2023)
Health Spending PC (logged)	Log-transformed government spending per capita on healthcare in current US dollars.	4.3759	1.1480	1.4929	7.1380	World Bank (2023)
Health GDP (logged)	Log-transformed government spending on healthcare as a percentage of GDP, in current US dollars.	1.5965	0.4065	0.2311	3.0160	World Bank (2023)
UNGA US	Country's voting alignment with the US in the United Nations General Assembly, scaled from −5 (low alignment) to 0 (high alignment).	−3.2508	0.6124	−4.8111	−1.3827	Bailey et al. (2016)
UNSC Temp	Binary variable indicating whether a country is a temporary member of the United Nations Security Council (1 = Yes, 0 = No).	0.0483	0.2260	0	1	Dreher et al. (2009b)

sender, intensity, economic focus, and whether the sanctions are unilateral or plurilateral. The construction of sanction explanatory variables adheres to methodologies commonly adopted in existing literature (e.g., Fu & Chang, 2024; Gutmann et al., 2024; Moteng et al., 2023; Wen et al., 2021).

International sanctions were first classified by the sender—namely, the US, EU, and UN—due to their significant political influence, which can have a stronger impact on developing countries. The *US Sanctions*, *EU Sanctions*, and *UN Sanctions* are binary variables, where 1 indicates a sanction imposed on a country-year by the specific sender, and 0 indicates otherwise. UN sanctions, considered multilateral, involve agreement among temporary and permanent members of the United Nations Security Council.

The study accounts for the varying intensity of international sanctions. When a country-year experiences multiple sanctions with different intensities, the approach selects the highest intensity value to construct a non-binary Intensity variable, ensuring it accurately reflects the most severe sanctions imposed. This variable, derived from Von Soest and Wahman (2015), captures a range of sanctions. A score of zero indicates no sanctions, one corresponds to targeted sanctions (e.g., asset freezes, diplomatic or visa bans), two reflects military-related sanctions (e.g., interruptions in military cooperation or arms embargoes), three represents partial or full suspension of aid, four involves a commodity embargo (excluding arms embargoes, which are scored as two), flight bans, or financial sanctions, and five signifies a comprehensive trade embargo, involving a total ban on trade and financial relations. This Intensity index is widely used in studies examining the effects of international sanctions, including Chen et al. (2019), Fu et al. (2020), Ko et al. (forthcoming), Fu and Chang (2024), Moteng et al. (2023), and Wen et al. (2021).

For the *Economic* binary variable, international sanctions were classified based on whether they specifically target the economy, following the classification by Von Soest and Wahman (2015), where 1 indicates an economic target and 0 indicates otherwise. Finally, sanctions were classified as *Unilateral* or *Plurilateral* under binary variable setup. According to existing literature (e.g., Chen et al., 2019; Fu & Chang, 2024; Moteng et al., 2023), a sanction is considered *Unilateral* if imposed solely by the US or EU, but *Plurilateral* if both entities impose sanctions in the same year. However, if the UN imposes sanctions, the variable is coded as *UN Sanctions*, regardless of whether the US and EU also impose sanctions.

Table 1 indicates that 31.64%, 27.79%, and 13.22% of observations were affected by US, EU, and UN sanctions, respectively, showing that the US imposes the most sanctions, followed by the EU, with the UN imposing the fewest. The intensity of sanctions has a mean of 1.2112 with a standard deviation of 1.6177, indicating that most sanctions are of low intensity. The mean value of the economic sanctions variable is 0.3316, suggesting that roughly one-third of the country-year observations experienced sanctions specifically targeting the economy. Additionally, 16.38% and 11.71% of observations involve unilateral or plurilateral sanctions, respectively, indicating that unilateral sanctions are more common than plurilateral or multilateral sanctions against target countries. The descriptive statistics of the explanatory variables, as presented in Table 1, align closely with findings from existing literature (e.g., Fu et al., 2020), reinforcing the reliability of the variable selection process.

The study uses four indicators of child immunization as the dependent variable: the percentage of children under one year old vaccinated with DPT, Hepatitis B, Measles, and Polio vaccines. These vaccines were selected due to their widespread use in preventing prevalent yet avoidable diseases that claim many young lives worldwide. Immunization rates for these vaccines provide relatively complete data from 2000 to 2019, suitable for country-year panel analysis, and are commonly employed to assess the impact of external political or economic pressures (e.g., Aaby et al., 2002; Daoud & Reinsberg, 2019). The average immunization rates for DPT, Hepatitis B, Measles, and Polio vaccines are 80.16%, 81.81%, 79.53%, and 81.10%, respectively, indicating relatively similar vaccination levels (Table 1). Fig. 1 presents the vaccination rates for Polio, DPT (Diphtheria, Pertussis, and Tetanus), HepB (Hepatitis B), and Measles across 76 countries over time, alongside the periods when these countries were subject to international sanctions, regardless of the sender, intensity, or type of sanctions.

The study also considers a range of covariates commonly used in literature examining the health impacts of international sanctions in a country-year panel setup (e.g., Daponte & Garfield, 2000; Gutmann et al., 2021; Miromanova, 2024; Peksen, 2021). These variables include GDP per capita, population (in millions), urbanization, dependency ratio, globalization, natural resource contribution to national GDP, natural resource rent contribution to national GDP, democracy, and foreign aid received per capita. All variables, except democracy, are log-transformed to account for large variations in their values.

2.3. Empirical modelling

This study employs a fixed-effects regression methodology to analyze the relationship between international sanctions and child vaccination rates. The panel data is unbalanced, and observations with missing data in any of the variables are excluded, following established practices in the literature. Since the proportion of missing data is below 5%, imputing values is unnecessary. Fixed-effects panel regression models are widely applied to assess the impact of international sanctions on target countries. To prevent multicollinearity and ensure precise estimates, the analysis examines different components of international sanctions separately, in line with previous studies (e.g., Chen et al., 2019; Early & Peksen, 2022; Fu et al., 2023; Hultman & Peksen, 2017; Moteng et al., 2023). This approach is particularly useful for longitudinal datasets, where observations cover multiple periods across countries, enabling the control of country-specific and year-specific effects. The regression equation is formulated as follows:

$$Vaccine_{\iota\tau} = \alpha_1 + \alpha_2 Sanctions_{\iota\tau-1} + \alpha_3 X_{\iota\tau-1} + \upsilon_\iota + \varsigma_\tau + \varepsilon_{\iota\tau} \quad (1)$$

In this equation, the dependent variable, *Vaccine*, refers to the immunization rate of a specific type of vaccine, such as *DPT*, *Hepatitis B*, or *Measles*, where ι and τ represent country and year dummies, respectively. The one-year lag $\tau - 1$ for all right-hand-side variables accounts for the possibility that the effects of international sanctions on child immunization are not immediate. *Sanctions* denote any of the seven sanction explanatory variables regressed separately, while *X* refers to all the covariates included in the regression. The terms υ_ι, ς_τ and $\varepsilon_{\iota\tau}$ represent the year-fixed effect, country-fixed effect, and error term, respectively.

To explore the potential interaction between international sanctions and government fiscal capacity on health spending, interaction terms are incorporated into the regression analysis as part of the robustness checks. In Equation (2), the sanction explanatory variables interact with health spending per capita, as shown in Tables A1-A4. In Equation (3), the sanction explanatory variables interact with health expenditure relative to national GDP, as shown in Tables A5-A8. These interactions examine how international sanctions, in conjunction with public health spending, might affect vaccine immunization rates in children. The equations incorporating these interactions are as follows:

$$Vaccine_{\iota\tau} = \alpha_1 + \alpha_2 (Sanctions_{\iota\tau-1}\ x\ HealthPC_{\iota\tau-1}) + \alpha_3 X_{\iota\tau-1} + \upsilon_\iota + \varsigma_\tau + \varepsilon_{\iota\tau} \quad (2)$$

$$Vaccine_{\iota\tau} = \alpha_1 + \alpha_2 (Sanctions_{\iota\tau-1}\ x\ HealthGDP_{\iota\tau-1}) + \alpha_3 X_{\iota\tau-1} + \upsilon_\iota + \varsigma_\tau + \varepsilon_{\iota\tau} \quad (3)$$

In these equations, *HealthPC* and *HealthGDP* denote health spending per capita and health spending relative to national GDP, respectively.

The robustness checks further include a heterogeneity test based on the level of economic development. Following existing studies (e.g., Ko et al., 2024a, Lee, & Leung, 2024), developing countries are classified

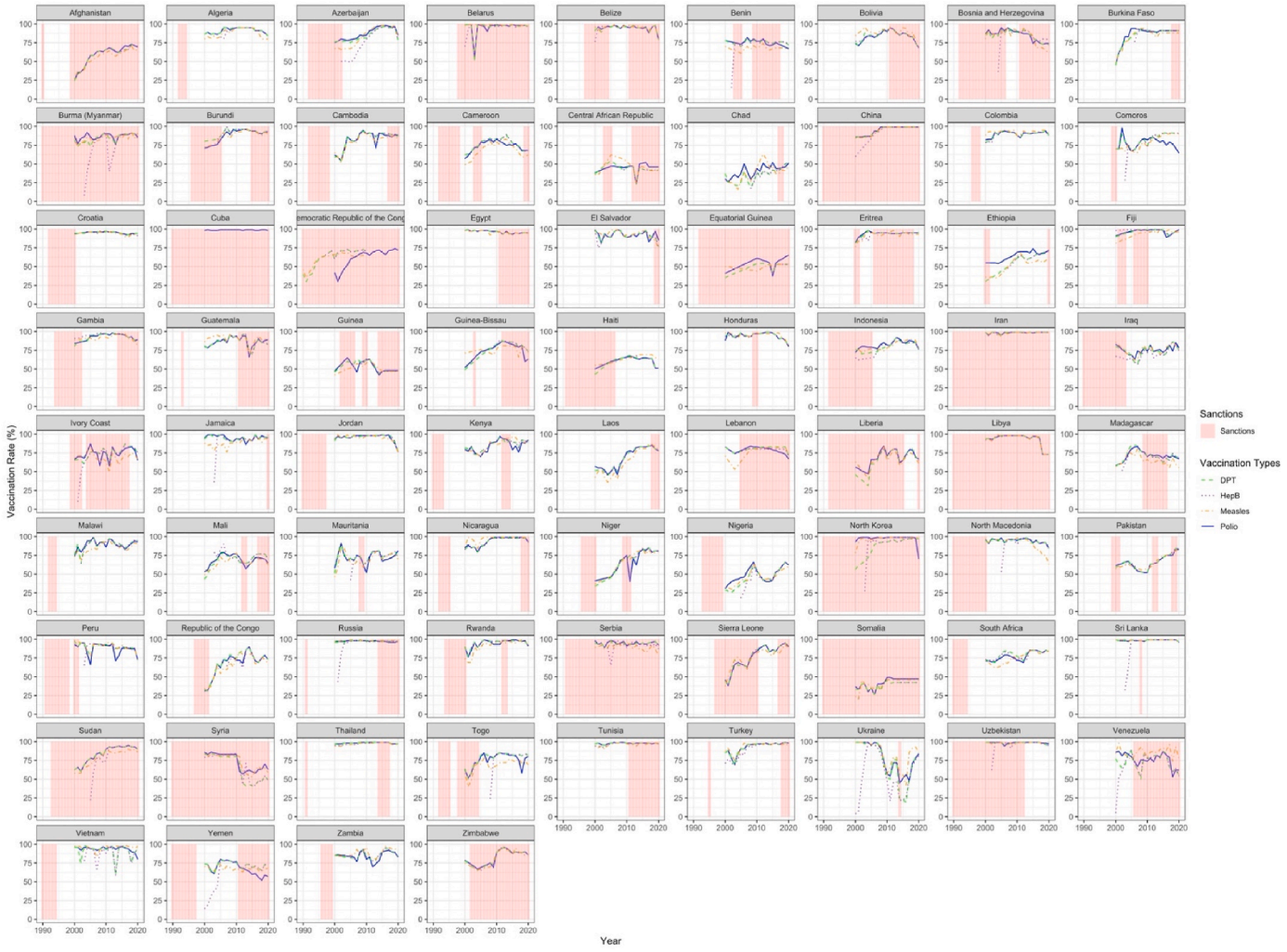

Fig. 1. Vaccination Rates and International Sanctions Across 76 Countries (2000–2019)
RemarkIn this diagram, international sanctions are coded in red as a dummy variable, indicating that the representation is independent of the sender, intensity, or type of sanctions. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

into two groups: poorer countries (low and lower-middle-income) and more affluent developing countries (upper-middle and high-income) according to the World Bank's 2024 income-level classification. Regression results for poorer developing countries are presented in Tables A9-A12, while results for more affluent developing countries are shown in Tables A13-A16.

To assess the duration of international sanctions' effects, this analysis includes lagged independent variables up to four years, a common approach for evaluating the persistence of such impacts (Dai et al., 2021). The dataset covers 121 out of 152 developing countries, including both treated and control groups, to strengthen the robustness of the findings. Thirty-one countries, particularly internationally unrecognized states or microstates like Saint Kitts and Nevis, are excluded due to the unavailability of relevant data for all three dependent variables in the World Bank (2024) database.

The analysis identifies 76 countries as treated, excluding those listed in Tables A21–A24, based on their experience of international sanctions at any point between 1990 and 2019, regardless of the sender, intensity, or type of sanctions. Additionally, 45 developing countries with available data between 1990 and 2019, but without any experience of international sanctions during that period, are designated as control countries (see Table A46 for details). While the panel regression models include control countries separately, the analysis combines treated and control countries to reduce potential selection bias and ensure the integrity of the results, as reflected in Tables A20–A24.

In addition to the fixed-effect regression, the study employs alternative models to address potential concerns related to autocorrelations, heteroscedasticity, and endogeneity. Panel-Corrected Standard Errors (PCSE) and Feasible Generalized Least Squares (FGLS) are applied to tackle autocorrelations and heteroscedasticity, following established methods from the literature (e.g., Ha & Thang, 2022; Ma et al., 2024). Recognizing that fixed-effect panel regression may not optimally address endogeneity, the analysis supplements it with two-stage least squares (2SLS) and System Generalized Method of Moments (GMM), or both, to ensure robust results that demonstrate the adverse impact of international sanctions on target countries (e.g., Chen et al., 2019; Moteng et al., 2023; Wang et al., 2019). System GMM is particularly effective in handling serial correlations and unobserved individual-specific effects. To enhance the treatment of endogeneity and mitigate potential statistical biases, the study conducts 2SLS using two distinct instruments: the country's voting affinity with the US in the United Nations General Assembly (Tables A33-A36) and the United Nations Security Council (Tables A37-A40). Additionally, System GMM results are presented in Tables A41-A44.

3. Empirical results

The analysis employed a fixed-effects panel regression model to

examine the relationship between international sanctions (explanatory variables) and vaccine coverage (dependent variables). Table 2 begins by exploring the correlation between international sanctions and *DPT* vaccination rates among children aged 12–23 months. The results in Models 1–3 indicate that when US, EU, or UN sanctions are present (indicated by a value of 1), the logged value of *DPT* vaccination rates decreases by 0.0407, 0.0384, and 0.0204, respectively. Notably, only US and EU sanctions show statistical significance at the 1% level, while UN sanctions do not demonstrate significant effects. In Model 4, the analysis reveals that an increase in the intensity of sanctions leads to a reduction in the logged *DPT* vaccination rate by 0.0131, again at a 1% significance level. Furthermore, Models 5–6 show that both *Intensity* and *Unilateral* sanctions negatively correlate with the logged *DPT* vaccination rate, with coefficients of −0.0534 and −0.0455, respectively, both significant at the 1% level. Conversely, Model 7 finds that *Plurilateral* sanctions do not have a significant negative correlation with *DPT* vaccination rates.

Table 3 shifts the focus to the association between international sanctions and the logged values of *Hepatitis B* immunization rates among children aged 12–23 months. In this analysis, only US sanctions demonstrate a significant negative association, with a coefficient of −0.0355. In contrast, EU and UN sanctions, along with the intensity variable, do not show significant associations. However, *Economic* and *Plurilateral* sanctions present significant correlations with the logged values of *Hepatitis B* immunization rates, with coefficients of −0.0393 and −0.0560, respectively, while *Unilateral* sanctions show no significant effect. This finding highlights the differential impact of various types of sanctions on *Hepatitis B* immunization.

Moving to Table 4, the regression results examine the impact of sanctions on the logged *Measles* immunization rates among children aged 12–23 months. The analysis reveals that an additional unit of US sanctions, EU sanctions, intensity, economic, and unilateral sanctions is significantly negatively associated with *Measles* immunization rates, with coefficients of −0.0473, −0.0287, −0.0400, −0.0146, −0.0458, and −0.0514, respectively. However, *Plurilateral* sanctions do not show statistical significance, suggesting that their impact on Measles immunization may be less pronounced than other types of sanctions.

Table 5 presents an analysis of the effect of sanctions on the logged Polio immunization rates among children aged 12–23 months. The findings indicate that EU sanctions, intensity, economic, unilateral, and plurilateral sanctions all correlate with reductions in the logged *Polio* immunization rate, with coefficients of −0.0450, −0.0096, −0.0331, −0.0322, and −0.0415, respectively. However, US and UN sanctions do not show significant negative coefficients. This suggests that while certain sanctions have a clear negative impact on *Polio* immunization rates, others may not be as influential.

To ensure the robustness of these findings, the analysis introduces an interaction term with *Health Spending Per Capita (PC)* to account for variations in immunization outcomes based on state healthcare investment. Table A1 reveals that US, EU, intensity, economic, and unilateral sanctions continue to negatively impact the *DPT* immunization rate, even when accounting for health spending. Similarly, Table A2 shows that US, economic, and plurilateral sanctions maintain a significant negative impact on *Hepatitis B* immunization. Interestingly, UN sanctions, when interacted with *Health Spending PC*, show a significant positive association with *Hepatitis B* immunization, though this result lacks consistency in subsequent robustness checks, indicating a need for cautious interpretation. Table A3 indicates that significant negative associations persist for all sanctions variables concerning *Measles* immunization, except for plurilateral and UN sanctions. Table A4 demonstrates that EU sanctions, intensity, economic, and unilateral sanctions, when interacting with *Health Spending PC*, are significantly negatively correlated with *Polio* immunization rates, consistent with the results shown in Table 5, except for *Plurilateral* sanctions, which show a significant negative coefficient in Table A5.

The analysis further explores the interaction between sanctions and national health spending relative to GDP (*Health GDP*) in Tables A5-A8. Table A5 shows that all sanctions, except *UN* and *Plurilateral* sanctions, have significant negative associations with *DPT* immunization rates. Table A6 indicates that only US, economic, and plurilateral sanctions negatively impact *Hepatitis B* vaccination, with UN sanctions displaying a significant positive association when interacting with *Health GDP*. Table A7 demonstrates that US, EU, intensity, economic, and unilateral sanctions consistently negatively affect *Measles* immunization rates, aligning with results in Table A3. Finally, Table A8 shows that EU, intensity, economic, unilateral, and plurilateral sanctions lead to a reduction in *Polio* vaccination rates among young children, although *Plurilateral* sanctions were previously statistically insignificant in Table A4.

To further investigate the contextual effects of international sanctions, a heterogeneity test is conducted. Tables A9-A12 classify low- and lower-middle-income developing countries as relatively less affluent, while Tables A13-A17 categorize upper-middle-income and high-income developing countries as more affluent. In poorer developing countries, Table A9 reveals that all sanctions variables, except UN sanctions, significantly negatively impact *DPT* vaccination rates. Table A10 shows that US, EU, economic, and plurilateral sanctions negatively affect *Hepatitis B* vaccination in poorer countries, while UN sanctions show no significant effect. Table A11 indicates that all sanctions variables, except *Plurilateral* sanctions, negatively correlate with *Measles* vaccination rates in poorer countries. Table A12 reveals that all sanctions variables, except US and UN sanctions, significantly undermine *Polio* vaccination coverage among children aged 12–23 months.

In contrast, the influence of international sanctions appears weaker in more affluent developing countries, though some negative associations persist. Notably, UN sanctions consistently show significant negative associations with all three types of immunization rates in more

Table 2
Fixed-effects panel regression of sanctions on DPT immunization among 1-year-Olds in target countries.

DPT	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
US Sanctions	−0.0407[a] (0.0112)						
EU Sanctions		−0.0384[a] (0.0122)					
UN Sanctions			−0.0204 (0.0205)				
Intensity				−0.0131[a] (0.0039)			
Economic					−0.0534[a] (0.0109)		
Unilateral						−0.0455[a] (0.0117)	
Plurilateral							−0.0289 (0.0154)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1377	1377	1377	1377	1377	1377	1377
R-squared (adjusted)	0.1922	0.1902	0.1846	0.1909	0.1988	0.1933	0.1855

$p < 0.05$**, $p < 0.01$*.
The values in parentheses denote standard errors. All right-hand-side variables are lagged by one year.
[a] $p < 0.01$.

Table 3
Fixed-effects panel regression of sanctions on hepatitis B immunization among 1-year-Olds in 76 target countries.

HepB	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
US Sanctions	−0.0355[a] (0.0195)						
EU Sanctions		−0.0263 (0.0218)					
UN Sanctions			0.0521 (0.0358)				
Intensity				−0.0067 (0.0071)			
Economic					−0.0393[b] (0.0195)		
Unilateral						−0.0215 (0.0215)	
Plurilateral							−0.0560[b] (0.0267)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1174	1174	1174	1174	1174	1174	1174
R-squared (adjusted)	0.0724	0.0708	0.0714	0.0703	0.0730	0.0704	0.0737

$p < 0.01$***.
The values in parentheses denote standard errors. All right-hand-side variables are lagged by one year.
[a] $p < 0.01$.
[b] $p < 0.05$.

Table 4
Fixed-effects panel regression of sanctions on measles immunization among 1-year-Olds in 76 target countries.

Measles	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
US Sanctions	−0.0473[b] (0.0099)						
EU Sanctions		−0.0287[b] (0.0109)					
UN Sanctions			−0.0400[a] (0.0182)				
Intensity				−0.0146[b] (0.0035)			
Economic					−0.0458[b] (0.0097)		
Unilateral						−0.0514[b] (0.0104)	
Plurilateral							0.0009 (0.0137)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1377	1377	1377	1377	1377	1377	1377
R-squared (adjusted)	0.1965	0.1869	0.1856	0.1934	0.1963	0.1976	0.1825

$p < 0.01$*.
The values in parentheses denote standard errors. All right-hand-side variables are lagged by one year.
[a] $p < 0.05$.
[b] $p < 0.01$.

Table 5
Fixed-effects panel regression of sanctions on polio immunization among 1-year-Olds in 76 target countries.

Polio	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
US Sanctions	−0.0154 (0.0096)						
EU Sanctions		−0.0450[a] (0.0104)					
UN Sanctions			−0.0048 (0.0177)				
Intensity				−0.0096[a] (0.0033)			
Economic					−0.0331[a] (0.0094)		
Unilateral						−0.0322[a] (0.0098)	
Plurilateral							−0.0415[a] (0.0133)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1378	1378	1378	1378	1378	1378	1378
R-squared (adjusted)	0.1598	0.1700	0.1582	0.1634	0.1662	0.1589	0.1644

$p < 0.05$**, $p < 0.01$*.
The values in parentheses denote the standard errors. All right-hand-side-variables are lagged by one year.
[a] $p < 0.01$.

affluent countries. However, other sanctions variables present a more complex picture. For instance, Table A14 reveals that economic sanctions are unexpectedly associated with higher *Hepatitis B* vaccination rates in more affluent countries, suggesting a different impact of economic sanctions within this context. Table A15 shows that US and Plurilateral sanctions exhibit positive associations with *Measles* vaccination in more affluent developing countries, while Unilateral sanctions show a negative association. Table A16 indicates that *Unilateral* sanctions weaken *Polio* vaccination rates in more affluent developing countries. These results suggest that while poorer developing countries tend to align more consistently with the main findings in Tables 2–5, more affluent developing countries exhibit relatively weaker impacts of international sanctions on vaccination rates. Nonetheless, UN sanctions consistently show negative associations across all types of vaccines in affluent countries, contrasting with their minimal impact in poorer countries.

To evaluate the long-term effects of international sanctions, analyses were conducted with varying lags of the explanatory sanction variables,

from zero to four years. Table A17 shows that US, EU, and Unilateral sanctions consistently show significant negative associations with *DPT* vaccination rates across zero to four lagged years, though the association slightly weakens over time. *Intensity* and *Economic* sanctions display significant negative associations for up to three lagged years, with marginal effects in the fourth year. Table A18 indicates that sanctions primarily affect *Hepatitis B* immunization in the short term, with *Economic* and *Plurilateral* sanctions showing significant negative associations without lag, while other sanctions variables lack statistical significance. Table A19 reveals that, except for *Plurilateral* sanctions, all variables maintain significant negative associations with Measles immunization from zero to four lagged years, though the association weakens over time. Table A20 indicates that the effect of EU sanctions on Polio vaccination lasts up to three years, while *Intensity*, *Economic*, *Unilateral*, and *Plurilateral* sanctions show significant negative associations without lags.

The analysis includes a robustness check by expanding the dataset to encompass 76 treated and 45 control countries, with the latter experiencing no sanctions at any point between 1990 and 2019. Table A21 confirms findings consistent with those in Table 2, revealing significant negative associations between DPT vaccination rates and US, EU, intensity, economic, and unilateral sanctions. Similarly, Table A22 aligns with Table 3, showing that US, economic, and plurilateral sanctions significantly reduce Hepatitis B immunization rates. Table A23 reflects results consistent with Table 4, indicating negative effects of all sanctions on Measles vaccination rates, except for plurilateral sanctions. Finally, Table A24 confirms that all sanctions reduce Polio immunization rates, except for UN and US sanctions, mirroring the findings in Table 5.

To address potential heteroscedasticity and serial correlation, the study applies Feasible Generalized Least Squares (FGLS) and Panel-Corrected Standard Errors (PCSE) analyses. Tables A25 to A28 (FGLS) and Tables A29 to A32 (PCSE) compare these results with those in Tables 2–5, demonstrating consistent statistical power and similar patterns. Minor variations are observed, such as the non-significance of plurilateral sanctions for Hepatitis B immunization in the FGLS (Table A26) and PCSE analyses (Table A30). These alternative regression methods validate the robustness of the primary findings.

To address potential endogeneity, the study employed an instrumental variable 2SLS analysis. The first series of 2SLS analyses, presented in Tables A33-A36, used the country's voting affinity with the US in the United Nations General Assembly (UNGA) as the instrument. This approach is based on established literature suggesting that countries aligned with US voting patterns are more likely to receive financial aid from the US or Western-dominated intergovernmental organizations (e.g., Dreher et al., 2008). The second series of 2SLS analyses, shown in Tables A37-A40, used a country's temporary membership in the United Nations Security Council (UNSC) as the instrument, following literature indicating that temporary UNSC members are more likely to receive financial aid from the US or Western-dominated intergovernmental organizations (e.g., Dreher et al., 2009a).

The results of the 2SLS analyses confirm the strength of the instruments, as indicated by the Kleibergen-Paap F-statistics, which consistently exceed the threshold of 10, indicating no under-identification issues. Furthermore, the instruments show significant negative associations with sanction variables, consistent with previous studies. The Sargan Test results do not fall below the 5% level, suggesting no over-identification restrictions in the 2SLS models.

In the first series of 2SLS analyses using UNGA US voting affinity as the instrument (Tables A33-A36), most sanction variables, except for *Plurilateral* sanctions, significantly reduce *DPT*, *Measles*, and *Polio* immunization rates among the 1-year-old population in the 76 targeted countries. However, in Table A34, only EU sanctions, UN sanctions, and *Intensity* are associated with a decline in Hepatitis B immunization rates, while US sanctions, *Economic*, *Unilateral*, and *Plurilateral* sanctions do not show significant effects.

The second series of 2SLS analyses, using UNSC temporary membership as the instrument (Tables A37-A40), demonstrates that all sanction variables, except for *Plurilateral* sanctions, significantly undermine all four types of child vaccination (*DPT*, *Hepatitis B*, *Measles*, and *Polio*). These results underscore the consistent negative impact of sanctions on child immunization rates, with the exception of *Plurilateral* sanctions, which do not show significant effects in this context.

To further address endogeneity and other statistical concerns, such as autocorrelation, the study applied the System GMM method. This approach uses the lagged dependent variable as an instrument, in line with existing studies (e.g., Fu et al., 2023; Moteng et al., 2023; Wang et al., 2019). The p-value for first-order autoregressive (AR1) tests generally rejects the null hypothesis, indicating significant autocorrelation at the 10% level, except for Table A42. Both second-order autoregressive (AR2) tests and the Sargan test for over-identification restrictions support the null hypothesis, confirming the reliability and trustworthiness of the GMM estimation outcomes, with the exception of the regression on *Hepatitis B* vaccination.

Table A41 shows that US sanctions, EU sanctions, *Intensity*, *Economic*, and *Unilateral* sanctions reduce *DPT* immunization rates among the 1-year-old population. Table A42 indicates that only Unilateral sanctions negatively correlate with Hepatitis B immunization, though the results warrant caution due to the failure to reject the null hypothesis in the first-order autoregressive test. Table A43 demonstrates that US sanctions, *Intensity*, *Economic*, and *Unilateral* sanctions negatively affect *Measles* immunization rates in the 76 target countries. Finally, Table A44 suggests that EU sanctions, *Intensity*, *Economic*, *Unilateral*, and *Plurilateral* sanctions weaken *Polio* immunization rates.

In summary, the comprehensive analysis presented in Table 6 reveals that US sanctions generally undermine child vaccination rates for *DPT*, *Hepatitis B*, and *Measles*. EU sanctions, *Intensity*, *Economic*, and *Unilateral* sanctions show a significant negative impact on child vaccination rates for *DPT*, *Measles*, and *Polio*, but not *Hepatitis B*. UN and *Plurilateral* sanctions mostly do not significantly affect child vaccination rates. This series of statistical analyses offers novel insights into the specific types of international sanctions that affect vaccine immunization rates from a cross-national perspective. The robustness of these findings is reinforced through various methodological approaches, including fixed-effects regression, interaction terms with health spending, heterogeneity tests, 2SLS with instrumental variables, and System GMM, ensuring the reliability and validity of the conclusions drawn.

4. Discussion and conclusion

4.1. Reasons for the results

The adverse impact of international sanctions on public health in targeted countries has been widely documented. Studies such as those by Miromanova (2024) and Peksen (2011) have shown how sanctions can lead to detrimental health outcomes. Specifically, case studies like those by Østby et al. (2021) have examined the impact of sanctions on child vaccination access in individual countries. However, this study is the first to empirically analyze the effects of international sanctions on child vaccination rates using a comprehensive country-year panel analysis. The findings consistently indicate that international sanctions reduce the accessibility of child vaccinations in targeted countries.

One of the primary reasons for this reduction is the financial and legal repercussions that sanctions, especially those with higher intensity such as trade embargoes or financial restrictions, impose on financial sectors and exporters. According to Blanchet et al. (2021), entities may hesitate to engage with sanctioned countries due to fears of violating international sanctions. This reluctance, often resulting in over-compliance, leads to fewer vaccines being distributed within the targeted nation, ultimately lowering immunization rates among children.

Moreover, sanctions create significant barriers for vaccine suppliers

Table 6
Summary of regression results from Tables 2–5 and the Appendix.

	US	EU	UN	Intensity	Economic	Unilateral	Plurilateral
DPT Vaccination							
Main (Table 2)	–	–	/	–	–	–	/
Health Spending PC (A1)	–	–	/	–	–	–	/
Health GDP (A5)	–	–	/	–	–	–	/
Low to Lower-middle (A9)	–	–	/	–	–	–	–
Upper middle to high (A13)	/	/	–	/	/	/	/
Lagged (A17)	–	–	/	-^	-^	–	-^
Control + Treated (A21)	–	–	/	–	–	–	/
FGLS (A25)	–	–	/	–	–	–	/
PCSE (A29)	–	–	/	–	–	–	/
2SLS - UNGA (A33)	–	–	–	–	–	–	/
2SLS - UNSC (A37)	–	–	–	–	–	–	/
System GMM (A41)	–	–	/	–	–	–	/
Hepatitis B Vaccination							
Main (Table 3)	–	/	/	/	–	/	–
Health Spending PC (A2)	–	/	+	/	–	/	–
Health GDP (A6)	–	–	+	/	–	/	–
Low to Lower-middle (A10)	–	–	/	/	–	/	–
Upper middle to high (A14	/	/	–	/	+	/	/
Lagged (A18)	/	/	/	/	-^	/	-^
Control + Treated (A22)	–	/	/	/	–	/	–
FGLS (A26)	–	/	/	/	–	/	/
PCSE (A30)	–	/	/	/	–	/	/
2SLS - UNGA (A34)	/	–	–	–	/	/	/
2SLS - UNSC (A38)	–	–	–	–	–	–	/
System GMM (A42)	/	/	/	/	/	–	/
Measles Vaccination							
Main (Table 4)	–	–	–	–	–	–	/
Health Spending PC (A3)	–	–	/	–	–	–	/
Health GDP (A7)	–	–	/	–	–	–	/
Low to Lower-middle (A11)	–	–	–	–	–	–	/
Upper middle to high (A15)	+	/	–	/	/	–	–
Lagged (A19)	–	–	–	–	–	–	/
Control + Treated (A23)	–	–	–	–	–	–	/
FGLS (A27)	–	–	–	–	–	–	/
PCSE (A31)	–	–	–	–	–	–	/
2SLS - UNGA (A35)	–	–	–	–	–	–	/
2SLS - UNSC (A39)	–	–	–	–	–	–	/
System GMM (A43)	–	/	/	–	–	–	/
Polio Vaccination							
Main (Table 5)	/	–	/	–	–	–	–
Health Spending PC (A4)	/	–	/	–	–	–	–
Health GDP (A8)	/	–	/	–	–	–	–
Low to Lower-middle (A12)	/	–	/	–	–	–	–
Upper middle to high (A16)	/	/	–	/	/	–	/
Lagged (A20)	/	-^	/	-^	-^	-^	-^
Control + Treated (A24)	–	–	/	–	–	–	–
FGLS (A28)	/	–	/	–	–	–	–
PCSE (A32)	/	–	/	–	–	–	–
2SLS - UNGA (A36)	–	–	–	–	–	–	/
2SLS - UNSC (A40)	–	–	–	–	–	–	/
System GMM (A44)	/	–	/	–	–	–	/

"+" denotes a significant positive association.
"-" denotes a significant negative association.
"/" denotes no significant association.
"-^" denotes that not all lagged years show a negative association.

and exporters, further impeding the delivery of vaccines to sanctioned countries. This results in reduced immunization rates, as highlighted by Blanchet et al. (2021). The weakening of national economies under sanctions, particularly in poorer developing countries, exacerbates this issue. Sanctions destabilize financial systems, impairing governments' ability to fund healthcare adequately. This effect is particularly severe in countries with limited medical resources, where sanctions further strain an already fragile healthcare sector. In contrast, more affluent developing countries possess greater financial resources, which can help mitigate the impact of sanctions on their healthcare systems.

The findings also suggest that US sanctions tend to have a more substantial impact than EU sanctions. This observation aligns with existing studies (e.g., Peksen, 2011) and can be attributed to the US's hegemonic position in the global order. The US has a greater ability to influence global rules beyond its jurisdiction, allowing it to pressure entities, including multinational companies (Mallard & Sun, 2022) and other states (Matera, 2020), to enforce its sanctions. This pressure can lead to reduced vaccine availability in targeted countries, undermining child vaccination efforts.

Conversely, UN sanctions appear to have a lesser effect on international child vaccination rates. Two main reasons contribute to this: first, as Fu et al. (2020) note, other governments are often less willing to enforce UN sanctions without additional conditions to achieve their geopolitical goals. Second, if the EU and US view UN sanctions as insufficiently severe, they may impose additional sanctions to meet their objectives (Brzoska, 2015; Fu et al., 2020). This could explain why US and EU sanctions have a more significant adverse impact on child vaccination progress in target countries. Furthermore, plurilateral

sanctions are generally less effective than unilateral sanctions, as evidenced by studies like Bapat and Morgan (2009) and Wen et al. (2021). The complexity of coordinating sanctions between the US and EU, due to potential conflicts and geopolitical issues, may reduce their overall effectiveness.

Among the vaccines covered in this study, Hepatitis B appears to be less affected by international sanctions. Al-Busafi and Alwassief (2024) highlight the World Health Organization's (WHO) efforts to expand Hepatitis B vaccination coverage globally, aiming for its elimination by 2030. The WHO's advocacy for universal Hepatitis B vaccination since 2009 (Ward & Van Damme, 2017) and the commitment of resources have led to 97% of countries incorporating comprehensive Hepatitis B vaccination within 24 h of birth (Al-Busafi & Alwassief, 2024). These strong international vaccination efforts may mitigate the impact of sanctions on Hepatitis B immunization rates.

Interestingly, the study found that EU sanctions, but not US or UN sanctions, negatively impact Polio vaccination rates in targeted countries. This may be due to the continued role of several EU member states as key suppliers of innovative polio-related vaccines. Despite the increasing production of polio vaccines in developing countries like India and Brazil, EU countries such as France and the Netherlands remain significant production hubs (Bakker et al., 2011; Blume, 2005; Rey-Jurado et al., 2018). When the EU imposes sanctions, particularly those involving trade restrictions, these countries' obligation to comply with EU sanctions can significantly reduce the availability of polio vaccines in targeted nations, undermining their vaccination coverage.

4.2. Research implications and policy recommendations

This study's findings offer critical insights that pave the way for both future research and informed policy development. To better understand the intricate dynamics of how international sanctions disrupt vaccine access, future research should incorporate qualitative methods such as interviews with healthcare professionals, public health policymakers, and the communities directly impacted by sanctions. These approaches will uncover the real-world challenges and strategies employed to navigate the barriers imposed by sanctions on vaccine distribution.

Furthermore, research should delve deeply into how international sanctions affect the entire vaccine production and supply chain. This includes examining the disruptions in manufacturing, distribution, and procurement processes, particularly in countries heavily dependent on vaccine imports. By expanding the scope of research to include a wider range of vaccines, such as those for HPV, influenza, and COVID-19, a more comprehensive understanding of the broad public health implications of sanctions can be achieved.

In addition to these research directions, further cross-national analysis is essential to identify and understand the factors that either hinder or facilitate access to child vaccinations across different contexts. These factors might include the availability and effectiveness of international aid, the robustness of national health infrastructure, governance quality, and the crucial role of non-governmental organizations in mitigating the adverse effects of sanctions. Moreover, exploring the combined effects of international sanctions with external economic or political shocks—such as financial crises, political instability, or global pandemics—would provide valuable insights into how these compounded pressures influence vaccine accessibility and the resilience of healthcare systems.

From a policy perspective, the findings underscore the urgent need for targeted countries to strengthen their domestic capacity for vaccine production. Reducing reliance on imports is critical, and this could be achieved through strategic initiatives such as incentivizing local vaccine production, fostering partnerships with international pharmaceutical companies, and making significant investments in biotechnology infrastructure. These measures would not only enhance national self-sufficiency but also safeguard public health in the face of international sanctions.

Simultaneously, diplomatic efforts must be intensified to negotiate waivers or reductions in sanctions that pertain to essential medical supplies, including vaccines. Diplomacy should focus on emphasizing the humanitarian consequences of sanctions and advocating for exemptions for health-related goods and services. Such efforts could mitigate the unintended public health crises that often accompany stringent sanctions.

Global coordination plays a crucial role in ensuring that sanctions do not undermine international vaccination campaigns. International organizations, particularly the WHO, should lead in establishing robust mechanisms that protect public health by ensuring that essential medical supplies are exempt from sanctions. Sanctioning countries must also remain vigilant, monitoring the impact of their policies on public health in the targeted nations, and taking proactive steps to prevent sanctions from exacerbating public health emergencies. Where necessary, providing humanitarian aid or establishing alternative supply routes will be vital to maintain vaccine availability and protect vulnerable populations.

Supporting multilateral vaccine initiatives, such as those led by Gavi, the Vaccine Alliance, is another critical policy recommendation. Participation in these initiatives would promote equitable access to vaccines and help ensure that children in sanctioned countries receive the immunizations they need. This approach not only addresses immediate public health needs but also strengthens global health security by preventing the spread of infectious diseases.

In conclusion, this research highlights the pressing need for a multifaceted approach to mitigate the broad consequences of international sanctions on child vaccination rates. Strengthening domestic vaccine production capabilities, engaging in strategic diplomacy, and actively participating in international vaccine distribution efforts are essential steps in protecting public health under the constraints of sanctions. A comprehensive research agenda that further explores the complex interactions between sanctions, vaccine access, and external shocks will provide the insights necessary to guide effective and informed policy decisions in the future. This proactive approach will be instrumental in ensuring that all children, regardless of geopolitical circumstances, have access to life-saving vaccines and a healthier future.

CRediT authorship contribution statement

Jeremy Ko: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Chun Kai Leung:** Writing – review & editing, Visualization, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Harry Fung Lee:** Writing – review & editing, Validation, Supervision, Project administration, Conceptualization. **Wai Kit Ming:** Writing – review & editing, Validation, Funding acquisition.

Ethical statements

By submitting this work, we confirm the following.

1. The manuscript, titled "Barriers to Child Vaccination: The Role of International Sanctions," is written specifically for consideration by *SSM - Population Health*. It has not been published previously and is not currently under consideration for publication elsewhere.
2. The publication of this article is approved by all authors.
3. All authors are fully aware that if the manuscript is accepted, it will not be published elsewhere in the same form, in English or any other language, including electronically, without the written consent of the copyright holder.

Data availability statement

The variables used in this study are freely available from the following sources.

- Sanctions variables (https://www.giga-hamburg.de/en/publications/research-data/giga-sanctions-dataset) (https://www.globalsanctionsdatabase.com/):
- Vaccination rate variables (https://data.worldbank.org/indicator) (https://immunizationdata.who.int/):
- GDP Per Capita, Population, Urbanization, Dependency Ratio, Globalization, Natural Resource GDP %, Foreign Aid Per Capita, Health Spending PC, Health GDP (https://data.worldbank.org/indicator)
- UNGA US (https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/LEJUQZ)
- UNSC Temp (https://axel-dreher.de/datasets/)

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix

Table A1Fixed-Effect Panel Regression Analysis of Sanctions and Health Spending Per Capita on DPT Immunization Rates Among 1-Year-Olds in 76 Target Countries

DPT	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
US Sanctions x Health Spending PC	-0.0079***						
	(0.0027)						
EU Sanctions x Health Spending PC		-0.0074**					
		(0.0029)					
UN Sanctions x Health Spending PC			0.0021				
			(0.0049)				
Intensity x Health Spending PC				-0.0026***			
				(0.0009)			
Economic x Health Spending PC					-0.0107***		
					(0.0026)		
Unilateral x Health Spending PC						-0.0102***	
						(0.0028)	
Plurilateral x Health Spending PC							-0.0050
							(0.0036)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1293	1293	1293	1293	1293	1293	1293
R-squared (adjusted)	0.1474	0.1460	0.1416	0.1469	0.1533	0.1505	0.1429

p<0.01*.
The values in parentheses denote the standard errors. All right-hand-side-variables are lagged by one year.
** p<0.05
*** p<0.01

Table A2
Fixed-Effect Panel Regression Analysis of Sanctions and Health Spending Per Capita on Hepatitis B Immunization Rates Among 1-Year-Olds in 76 Target Countries

HepB	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
US Sanctions x Health Spending PC	-0.0081*						
	(0.0044)						
EU Sanctions x Health Spending PC		-0.0054					
		(0.0047)					
UN Sanctions x Health Spending PC			0.0167**				
			(0.0081)				
Intensity x Health Spending PC				-0.0017			
				(0.0016)			
Economic x Health Spending PC					-0.0103**		
					(0.0043)		
Unilateral x Health Spending PC						-0.0075	
						(0.0047)	
Plurilateral x Health Spending PC							-0.0126**
							(0.0058)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1129	1129	1129	1129	1129	1129	1129
R-squared (adjusted)	0.0626	0.0608	0.0634	0.0606	0.0648	0.0619	0.0637

p<0.01***,
The values in parentheses denote the standard errors. All right-hand-side-variables are lagged by one year.

* p<0.01.
** p<0.05,

Table A3
Fixed-Effect Panel Regression Analysis of Sanctions and Health Spending Per Capita on Measles Immunization Rates Among 1-Year-Olds in 76 Target Countries

Measles	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
US Sanctions x Health Spending PC	-0.0106*** (0.0024)						
EU Sanctions x Health Spending PC		-0.0056** (0.0026)					
UN Sanctions x Health Spending PC			-0.0018 (0.0044)				
Intensity x Health Spending PC				-0.0035*** (0.0008)			
Economic x Health Spending PC					-0.0093*** (0.0023)		
Unilateral x Health Spending PC						-0.0127*** (0.0025)	
Plurilateral x Health Spending PC							0.0003 (0.0032)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1293	1293	1293	1293	1293	1293	1293
R-squared (adjusted)	0.1602	0.1502	0.1470	0.1592	0.1581	0.1647	0.1468

p<0.01*.
The values in parentheses denote the standard errors. All right-hand-side-variables are lagged by one year.
** p<0.05,
*** p<0.01,

Table A4
Fixed-Effect Panel Regression Analysis of Sanctions and Health Spending Per Capita on Polio Immunization Rates Among 1-Year-Olds in 76 Target Countries

Polio	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
US Sanctions x Health Spending PC	-0.0023 (0.0023)						
EU Sanctions x Health Spending PC		-0.0074*** (0.0025)					
UN Sanctions x Health Spending PC			0.0018 (0.0042)				
Intensity x Health Spending PC				-0.0017** (0.0008)			
Economic x Health Spending PC					-0.0052** (0.0022)		
Unilateral x Health Spending PC						-0.0070*** (0.0024)	
Plurilateral x Health Spending PC							-0.0053* (0.0031)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1285	1285	1285	1285	1285	1285	1285
R-squared (adjusted)	0.1004	0.1064	0.0998	0.1029	0.1038	0.1059	0.1019

The values in parentheses denote the standard errors. All right-hand-side-variables are lagged by one year.
* p<0.01.
** p<0.05,
*** p<0.01,

Table A5
Fixed-Effect Panel Regression Analysis of the Interaction Between Sanctions and Health Spending Relative to National GDP on DPT Immunization Rates Among 1-Year-Olds in 76 Target Countries

DPT	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
US Sanctions x Health GDP	-0.0159** (0.0069)						
EU Sanctions x Health GDP		-0.0222*** (0.0075)					
UN Sanctions x Health GDP			-0.0085 (0.0115)				
Intensity x Health GDP				-0.0068*** (0.0025)			
Economic x Health GDP					-0.0286*** (0.0070)		

(continued on next page)

Table A5 (*continued*)

DPT	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Unilateral x Health GDP						-0.0208***	
						(0.0074)	
Plurilateral x Health GDP							-0.0149
							(0.0097)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1293	1293	1293	1293	1293	1293	1293
R-squared (adjusted)	0.1452	0.1476	0.1419	0.1467	0.1533	0.1470	0.1432

p<0.01*.
The values in parentheses denote the standard errors. All right-hand-side-variables are lagged by one year.
** p<0.05,
*** p<0.01,

Table A6
Fixed-Effect Panel Regression Analysis of the Interaction Between Sanctions and Health Spending Relative to National GDP on Hepatitis B Immunization Rates Among 1-Year-Olds in 76 Target Countries

HepB	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
US Sanctions x Health GDP	-0.0222*						
	(0.0114)						
EU Sanctions x Health GDP		-0.0216*					
		(0.0127)					
UN Sanctions x Health GDP			0.0326*				
			(0.0197)				
Intensity x Health GDP				-0.0050			
				(0.0041)			
Economic x Health GDP					-0.0302**		
					(0.0117)		
Unilateral x Health GDP						-0.0157	
						(0.0125)	
Plurilateral x Health GDP							-0.0427***
							(0.0159)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1129	1129	1129	1129	1129	1129	1129
R-squared (adjusted)	0.0630	0.0622	0.0620	0.0608	0.0655	0.0610	0.0660

The values in parentheses denote the standard errors. All right-hand-side-variables are lagged by one year.
* p<0.01.
** p<0.05,
*** p<0.01,

Table A7
Fixed-Effect Panel Regression Analysis of the Interaction Between Sanctions and Health Spending Relative to National GDP on Measles Immunization Rates Among 1-Year-Olds in 76 Target Countries

Measles	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
US Sanctions x Health GDP	-0.0219***						
	(0.0061)						
EU Sanctions x Health GDP		-0.0108*					
		(0.0066)					
UN Sanctions x Health GDP			-0.0091				
			(0.0101)				
Intensity x Health GDP				-0.0076***			
				(0.0022)			
Economic x Health GDP					-0.0235***		
					(0.0062)		
Unilateral x Health GDP						-0.0288***	
						(0.0065)	
Plurilateral x Health GDP							0.0036
							(0.0086)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1293	1293	1293	1293	1293	1293	1293
R-squared (adjusted)	0.1557	0.1487	0.1474	0.1553	0.1569	0.1603	0.1470

p<0.05**,
The values in parentheses denote the standard errors. All right-hand-side-variables are lagged by one year.
* p<0.01.
*** p<0.01,

Table A8
Fixed-Effect Panel Regression Analysis of the Interaction Between Sanctions and Health Spending Relative to National GDP on Polio Immunization Rates Among 1-Year-Olds in 76 Target Countries

Polio	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
US Sanctions x Health GDP	-0.0026 (0.0059)						
EU Sanctions x Health GDP		-0.0233*** (0.0064)					
UN Sanctions x Health GDP			-0.0062 (0.0098)				
Intensity x Health GDP				-0.0047** (0.0021)			
Economic x Health GDP					-0.0143** (0.0059)		
Unilateral x Health GDP						-0.0142** (0.0063)	
Plurilateral x Health GDP							-0.0192** (0.0083)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1291	1291	1291	1291	1291	1291	1291
R-squared (adjusted)	0.0998	0.1095	0.1000	0.1034	0.1040	0.1034	0.1036

p<0.01*.
The values in parentheses denote the standard errors. All right-hand-side-variables are lagged by one year.
** p<0.05,
*** p<0.01

Table A9
Fixed-Effect Panel Regression Analysis of Sanctions Impact on DPT Immunization Rates Among One-Year-Olds in Low to Lower-Middle Income Countries

DPT	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
US Sanctions	-0.0354*** (0.0131)						
EU Sanctions		-0.0547*** (0.0152)					
UN Sanctions			-0.0330 (0.0257)				
Intensity				-0.0121** (0.0047)			
Economic					-0.0138*** (0.0043)		
Unilateral						-0.0384*** (0.0140)	
Plurilateral							-0.0476** (0.0197)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1016	1016	1016	1016	1016	1016	1016
R-squared (adjusted)	0.1401	0.1451	0.1349	0.1393	0.1561	0.1402	0.1388

p<0.01*.
The values in parentheses denote the standard errors. All right-hand-side-variables are lagged by one year.
** p<0.05,
*** p<0.01,

Table A10
Fixed-Effect Panel Regression Analysis of Sanctions Impact on Hepatitis B Immunization Rates Among One-Year-Olds in Low to Lower-Middle Income Countries

HepB	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
US Sanctions	-0.0372* (0.0227)						
EU Sanctions		-0.0459* (0.0277)					
UN Sanctions			0.0536 (0.0442)				
Intensity				-0.0081 (0.0086)			
Economic					-0.0604** (0.0235)		
Unilateral						-0.0272 (0.0253)	
Plurilateral							-0.0818** (0.0343)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	877	877	877	877	877	877	877
R-squared (adjusted)	0.0356	0.0358	0.0341	0.0332	0.0402	0.0338	0.0392

p<0.01***,
The values in parentheses denote the standard errors. All right-hand-side-variables are lagged by one year.
* p<0.01.
** p<0.05,

Table A11
Fixed-Effect Panel Regression Analysis of Sanctions Impact on Measles Immunization Rates Among One-Year-Olds in Low to Lower-Middle Income Countries

Measles	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
US Sanctions	-0.0443*** (0.0113)						
EU Sanctions		-0.0347*** (0.0132)					
UN Sanctions			-0.0413* (0.0221)				
Intensity				-0.0131*** (0.0041)			
Economic					-0.0587*** (0.0112)		
Unilateral						-0.0453*** (0.0121)	
Plurilateral							-0.0141 (0.0170)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1018	1018	1018	1018	1018	1018	1018
R-squared (adjusted)	0.1761	0.1687	0.1657	0.1717	0.1863	0.1750	0.1632

p<0.05**
The values in parentheses denote the standard errors. All right-hand-side-variables are lagged by one year.
* p<0.01.
*** p<0.01,

Table A12
Fixed-Effect Panel Regression Analysis of Sanctions Impact on Polio Immunization Rates Among One-Year-Olds in Low to Lower-Middle Income Countries

Polio	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
US Sanctions	-0.0125 (0.0111)						
EU Sanctions		-0.0533*** (0.0129)					
UN Sanctions			-0.0081 (0.0217)				
Intensity				-0.0084** (0.0040)			
Economic					-0.0423*** (0.0111)		
Unilateral						-0.0245** (0.0120)	
Plurilateral							-0.0636*** (0.0166)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1029	1029	1029	1029	1029	1029	1029
R-squared (adjusted)	0.1230	0.1372	0.1219	0.1258	0.1349	0.1256	0.1351

p<0.01*.
The values in parentheses denote the standard errors. All right-hand-side-variables are lagged by one year.
** p<0.05,
*** p<0.01,

Table A13
Fixed-Effect Panel Regression Analysis of Sanctions Impact on DPT Immunization Rates Among One-Year-Olds in Upper-Middle to High-Income Countries

DPT	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
US Sanctions	0.0284 (0.0188)						
EU Sanctions		-0.0064 (0.0123)					
UN Sanctions			-0.0393* (0.0205)				
Intensity				0.0011 (0.0051)			
Economic					0.0204 (0.0153)		

(*continued on next page*)

Table A13 (*continued*)

DPT	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Unilateral						-0.0327 (0.0223)	
Plurilateral							0.0224 (0.0167)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	284	284	284	284	284	284	284
R-squared (adjusted)	0.0601	0.0526	0.0653	0.0517	0.0582	0.0597	0.0584

p<0.01***, p<0.05**,
The values in parentheses denote the standard errors. All right-hand-side-variables are lagged by one year.
* p<0.01.

Table A14
Fixed-Effect Panel Regression Analysis of Sanctions Impact on Hepatitis B Immunization Rates Among One-Year-Olds in Upper-Middle to High-Income Countries

HepB	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
US Sanctions	0.0318 (0.0199)						
EU Sanctions		0.0023 (0.0133)					
UN Sanctions			-0.0392* (0.0233)				
Intensity				0.0054 (0.0055)			
Economic					0.0277* (0.0167)		
Unilateral						-0.0142 (0.0239)	
Plurilateral							0.0261 (0.0180)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	270	270	270	270	270	270	270
R-squared (adjusted)	0.0802	0.0703	0.0813	0.0739	0.0809	0.0716	0.0785

p<0.01***, p<0.05**,
The values in parentheses denote the standard errors. All right-hand-side-variables are lagged by one year.
* p<0.01.

Table A15
Fixed-Effect Panel Regression Analysis of Sanctions Impact on Measles Immunization Rates Among One-Year-Olds in Upper-Middle to High-Income Countries

Measles	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
US Sanctions	0.0444** (0.0224)						
EU Sanctions		-0.0130 (0.0147)					
UN Sanctions			-0.0521** (0.0244)				
Intensity				0.0020 (0.0061)			
Economic					0.0284 (0.0182)		
Unilateral						-0.0556** (0.0265)	
Plurilateral							0.03921** (0.0198)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	270	270	270	270	270	270	270
R-squared (adjusted)	0.1904	0.1801	0.1923	0.1779	0.1854	0.1918	0.1903

p<0.01***, p<0.01*.
The values in parentheses denote the standard errors. All right-hand-side-variables are lagged by one year.
** p<0.05,

Table A16
Fixed-Effect Panel Regression Analysis of Sanctions Impact on Polio Immunization Rates Among One-Year-Olds in Upper-Middle to High-Income Countries

Polio	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
US Sanctions	0.0217 (0.0213)						
EU Sanctions		-0.0150 (0.0139)					
UN Sanctions			-0.0491** (0.0231)				
Intensity				-0.0024 (0.0058)			
Economic					0.0172 (0.0173)		
Unilateral						-0.0424* (0.0252)	
Plurilateral							0.0168 (0.0189)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	284	284	284	284	284	284	284
R-squared (adjusted)	0.0228	0.0233	0.0362	0.0194	0.0226	0.0298	0.0218

p<0.01***,
The values in parentheses denote the standard errors. All right-hand-side-variables are lagged by one year.

* p<0.01.
** p<0.05,

Table A17
Fixed-Effect Panel Regression Analysis of Sanctions Impact on DPT Immunization Rates Among One-Year-Olds Lagged by 0-4 Years (Excluding One-Year Lag) in 76 Target Countries

DPT	0 Year	2 Years	3 Years	4 Years
US Sanctions	-0.0286*** (0.0109)	-0.0376*** (0.0113)	-0.0340*** (0.0114)	-0.0257** (0.0116)
EU Sanctions	-0.0319*** (0.0122)	-0.0419*** (0.0120)	-0.0349*** (0.0121)	-0.0259** (0.0122)
UN Sanctions	-0.0186 (0.0200)	-0.0253 (0.0209)	-0.0333 (0.0216)	-0.0126 (0.0218)
Intensity	-0.0113*** (0.0039)	-0.0105*** (0.0039)	-0.0092** (0.0039)	-0.0062 (0.0039)
Economic	-0.0487*** (0.0108)	-0.0401*** (0.0109)	-0.0331*** (0.0110)	-0.0152 (0.0110)
Unilateral	-0.0425*** (0.01157)	-0.0351*** (0.0119)	-0.0423*** (0.0120)	-0.0382*** (0.0120)
Plurilateral	-0.0131 (0.0154)	-0.0304** (0.0150)	-0.0160 (0.0150)	-0.0112 (0.0154)

p<0.01*.
The values in parentheses indicate the standard errors. All right-hand-side variables are lagged by one year. Each model includes control variables, country-year effects, and year-fixed effects, though these are not displayed due to space constraints. Each row represents a distinct panel, with regression analysis conducted separately for each box, rather than combining all sanction-related variables into a single analysis per column.
** p<0.05,
*** p<0.01,

Table A18
Fixed-Effect Panel Regression Analysis of Sanctions Impact on Hepatitis B Immunization Rates Among One-Year-Olds Lagged by 0-4 Years (Excluding One-Year Lag) in 76 Target Countries

HepB	0 Year	2 Years	3 Years	4 Years
US Sanctions	-0.0276 (0.0191)	-0.0254 (0.0200)	0.0011 (0.0205)	0.0086 (0.0207)
EU Sanctions	-0.0199 (0.0215)	-0.0040 (0.0220)	0.0023 (0.0221)	0.0039 (0.0220)
UN Sanctions	0.0511 (0.0352)	0.0559 (0.0369)	0.0595 (0.0380)	0.0498 (0.0398)
Intensity	-0.0060 (0.0070)	-0.0033 (0.0071)	0.0034 (0.0071)	0.0046 (0.0070)
Economic	-0.0339* (0.0192)	-0.0294 (0.0198)	-0.0137 (0.0200)	-0.0052 (0.0199)
Unilateral	-0.0214 (0.0209)	0.0288 (0.0218)	-0.0215 (0.0219)	-0.0256 (0.0218)
Plurilateral	-0.0520* (0.0265)	-0.0205 (0.0265)	0.0019 (0.0267)	0.0186 (0.0270)

p<0.01***, p<0.05**,
The values in parentheses indicate the standard errors. All right-hand-side variables are lagged by one year. Each model includes control variables, country-year effects, and year-fixed effects, though these are not displayed due to space constraints. Each row represents a distinct panel, with regression analysis conducted separately for each box, rather than combining all sanction-related variables into a single analysis per column.
* p<0.01.

Table A19
Fixed-Effect Panel Regression Analysis of Sanctions Impact on Measles Immunization Rates Among One-Year-Olds Lagged by 0-4 Years (Excluding One-Year Lag) in 76 Target Countries

Measles	0 Year	2 Years	3 Years	4 Years
US Sanctions	-0.0397*** (0.0096)	-0.0390*** (0.0100)	-0.0337*** (0.0101)	-0.0273*** (0.0103)
EU Sanctions	-0.0227** (0.0109)	-0.0370*** (0.0107)	-0.0308*** (0.0107)	-0.0252** (0.0109)
UN Sanctions	-0.0304* (0.0177)	-0.0543*** (0.0186)	-0.0646*** (0.0192)	-0.0375* (0.0195)
Intensity	-0.0146*** (0.0034)	-0.0130*** (0.0035)	-0.0123*** (0.0034)	-0.0101*** (0.0034)
Economic	-0.0435*** (0.0096)	-0.0383*** (0.0097)	-0.0331*** (0.0097)	-0.0246** (0.0099)
Unilateral	-0.0533*** (0.0102)	-0.0415*** (0.0105)	-0.0463*** (0.0106)	-0.0426*** (0.0108)
Plurilateral	0.0079 (0.0136)	-0.0079 (0.0134)	0.0003 (0.0134)	0.0043 (0.0138)

The values in parentheses indicate the standard errors. All right-hand-side variables are lagged by one year. Each model includes control variables, country-year effects, and year-fixed effects, though these are not displayed due to space constraints. Each row represents a distinct panel, with regression analysis conducted separately for each box, rather than combining all sanction-related variables into a single analysis per column.
* p<0.01.
** p<0.05,
*** p<0.01,

Table A20
Fixed-Effect Panel Regression Analysis of Sanctions Impact on Polio Immunization Rates Among One-Year-Olds Lagged by 0-4 Years (Excluding One-Year Lag) in 76 Target Countries

Polio	0 Year	2 Years	3 Years	4 Years
US Sanctions	-0.0018 (0.0094)	0.0175 (0.0140)	0.0113 (0.0104)	0.0191 (0.0120)
EU Sanctions	-0.0347*** (0.0105)	-0.0264** (0.0113)	-0.0220* (0.0117)	-0.0077 (0.0122)
UN Sanctions	-0.0042 (0.0174)	-0.0213 (0.0193)	-0.0201 (0.0202)	-0.0219 (0.0208)
Intensity	-0.0059* (0.0033)	-0.0045 (0.0036)	-0.0056 (0.0038)	-0.0044 (0.0040)
Economic	-0.0211** (0.0093)	-0.0057 (0.0101)	-0.0060 (0.0105)	0.0068 (0.0110)
Unilateral	-0.0248** (0.0099)	-0.0073 (0.0111)	-0.0020 (0.0116)	0.0017 (0.0124)
Plurilateral	-0.0258* (0.0134)	-0.0107 (0.0146)	-0.0179 (0.0153)	-0.0040 (0.0158)

The values in parentheses indicate the standard errors. All right-hand-side variables are lagged by one year. Each model includes control variables, country-year effects, and year-fixed effects, though these are not displayed due to space constraints. Each row represents a distinct panel, with regression analysis conducted separately for each box, rather than combining all sanction-related variables into a single analysis per column.
* p<0.01.
** p<0.05,
*** p<0.01,

Table A21
Fixed-Effect Panel Regression Analysis of Sanctions Impact on DPT Immunization Rates Among One-Year-Olds in Control and Treated Developing Countries

DPT	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
US Sanctions	-0.0407***						
	(0.0112)						
EU Sanctions		-0.0384***					
		(0.0122)					
UN Sanctions			-0.0204				
			(0.0205)				
Intensity				-0.0131***			
				(0.0039)			
Economic					-0.0534***		
					(0.0109)		
Unilateral						-0.0455***	
						(0.0117)	
Plurilateral							-0.0239
							(0.0154)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1377	1377	1377	1377	1377	1377	1377
R-squared (adjusted)	0.1922	0.1902	0.1846	0.1909	0.1988	0.1933	0.1855

p<0.05**, p<0.01*.
The values in parentheses denote the standard errors. All right-hand-side-variables are lagged by one year.
*** p<0.01,

Table A22
Fixed-Effect Panel Regression Analysis of Sanctions Impact on Hepatitis B Immunization Rates Among One-Year-Olds in Control and Treated Developing Countries

HepB	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
US Sanctions	-0.0355* (0.0195)						
EU Sanctions		-0.0263 (0.0218)					
UN Sanctions			0.0521 (0.0358)				
Intensity				-0.0067 (0.0071)			
Economic					-0.0393** (0.0195)		
Unilateral						-0.0215 (0.0215)	
Plurilateral							-0.0590** (0.0267)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1377	1377	1377	1377	1377	1377	1377
R-squared (adjusted)	0.0724	0.0708	0.0714	0.0703	0.0730	0.0704	0.0737

p<0.01***,
The values in parentheses denote the standard errors. All right-hand-side-variables are lagged by one year.
* p<0.01.
** p<0.05,

Table A23
Fixed-Effect Panel Regression Analysis of Sanctions Impact on Measles Immunization Rates Among One-Year-Olds in Control and Treated Developing Countries

Measles	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
US Sanctions	-0.0397***						
	(0.0096)						
EU Sanctions		-0.0227**					
		(0.0109)					
UN Sanctions			-0.0304*				
			(0.0177)				
Intensity				-0.0145***			
				(0.0034)			
Economic					-0.0435***		
					(0.0096)		
Unilateral						-0.0533***	
						(0.0102)	

(continued on next page)

Table A23 (*continued*)

Measles	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Plurilateral							0.0079 (0.0136)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1386	1386	1386	1386	1386	1386	1386
R-squared (adjusted)	0.2140	0.2065	0.2056	0.2145	0.2161	0.2200	0.2040

The values in parentheses denote the standard errors. All right-hand-side-variables are lagged by one year.
* p<0.01.
** p<0.05,
*** p<0.01,

Table A24
Fixed-Effect Panel Regression Analysis of Sanctions Impact on Polio Immunization Rates Among One-Year-Olds in Control and Treated Developing Countries

Polio	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
US Sanctions	-0.0147 (0.0093)						
EU Sanctions		-0.0459*** (0.0102)					
UN Sanctions			-0.0121 (0.0172)				
Intensity				-0.0109*** (0.0032)			
Economic					-0.0332*** (0.0090)		
Unilateral						-0.0331*** (0.0099)	
Plurilateral							-0.0422*** (0.0129)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	2622	2622	2622	2622	2622	2622	2622
R-squared (adjusted)	0.1109	0.1172	0.1102	0.1140	0.1148	0.1140	0.1138

p<0.05**, p<0.01*.
The values in parentheses denote the standard errors. All right-hand-side-variables are lagged by one year.
*** p<0.01,

Table A25
FGLS Regression Analysis of Sanctions Impact on DPT Immunization Rates Among One-Year-Olds in 76 Target Countries

DPT	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
US Sanctions	-0.0407** (0.0197)						
EU Sanctions		-0.0384** (0.0176)					
UN Sanctions			-0.0204 (0.0267)				
Intensity				-0.0131** (0.0059)			
Economic					-0.0534** (0.0212)		
Unilateral						-0.0455** (0.0206)	
Plurilateral							-0.0239 (0.0251)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1377	1377	1377	1377	1377	1377	1377
R-squared (adjusted)	0.1922	0.1902	0.1846	0.1909	0.1987	0.1933	0.1855

p<0.01***, p<0.01*.
The values in parentheses denote the standard errors. All right-hand-side-variables are lagged by one year.
** p<0.05,

Table A26
FGLS Regression Analysis of Sanctions Impact on Hepatitis B Immunization Rates Among One-Year-Olds in 76 Target Countries

HepB	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
US Sanctions	-0.0355** (0.0178)						
EU Sanctions		-0.0263 (0.0220)					
UN Sanctions			0.0521 (0.0575)				
Intensity				-0.0067 (0.0068)			

(*continued on next page*)

Table A26 (*continued*)

HepB	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Economic					-0.0393** (0.0184)		
Unilateral						-0.0215 (0.0213)	
Plurilateral							-0.0590 (0.0419)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1377	1377	1377	1377	1377	1377	1377
R-squared (adjusted)	0.0724	0.0708	0.0714	0.0703	0.0730	0.0704	0.0737

p<0.01***, p<0.01*.
The values in parentheses denote the standard errors. All right-hand-side-variables are lagged by one year.
** p<0.05,

Table A27
FGLS Regression Analysis of Sanctions Impact on Measles Immunization Rates Among One-Year-Olds in 76 Target Countries

Measles	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
US Sanctions	-0.0473** (0.0184)						
EU Sanctions		-0.0287** (0.0144)					
UN Sanctions			-0.0400** (0.0202)				
Intensity				-0.0146*** (0.0052)			
Economic					-0.0458** (0.0196)		
Unilateral						-0.0514** (0.0208)	
Plurilateral							0.0459 (0.0494)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1377	1377	1377	1377	1377	1377	1377
R-squared (adjusted)	0.1965	0.1869	0.1856	0.1934	0.1963	0.1976	0.1825

p<0.01*.
The values in parentheses denote the standard errors. All right-hand-side-variables are lagged by one year.
** p<0.05,
*** p<0.01,

Table A28
FGLS Regression Analysis of Sanctions Impact on Polio Immunization Rates Among One-Year-Olds in 76 Target Countries

Polio	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
US Sanctions	-0.0155 (0.0096)						
EU Sanctions		-0.0450*** (0.0104)					
UN Sanctions			-0.0048 (0.0177)				
Intensity				-0.0096*** (0.0033)			
Economic					-0.0331*** (0.0094)		
Unilateral						-0.0321*** (0.0101)	
Plurilateral							-0.0415*** (0.0133)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1378	1378	1378	1378	1378	1378	1378
R-squared (adjusted)	0.1598	0.1700	0.1582	0.1634	0.1662	0.1646	0.1644

p<0.05**, p<0.01*.
The values in parentheses denote the standard errors. All right-hand-side-variables are lagged by one year.
*** p<0.01,

Table A29
PCSE Regression Analysis of Sanctions Impact on DPT Immunization Rates Among One-Year-Olds in 76 Target Countries

DPT	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
US Sanctions	-0.0407** (0.0195)						
EU Sanctions		-0.0384** (0.0173)					
UN Sanctions			-0.0204 (0.0262)				
Intensity				-0.0131** (0.0058)			
Economic					-0.0534** (0.0209)		
Unilateral						-0.0455** (0.0203)	
Plurilateral							-0.0239 (0.0247)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1377	1377	1377	1377	1377	1377	1377
R-squared (adjusted)	0.1922	0.1902	0.1846	0.2363	0.1988	0.1933	0.1855

p<0.01***, p<0.01*.
The values in parentheses denote the standard errors. All right-hand-side-variables are lagged by one year.
** p<0.05,

Table A30
PCSE Regression Analysis of Sanctions Impact on Hepatitis B Immunization Rates Among One-Year-Olds in 76 Target Countries

HepB	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
US Sanctions	-0.0355** (0.0176)						
EU Sanctions		-0.0263 (0.0217)					
UN Sanctions			0.0521 (0.0566)				
Intensity				-0.0067 (0.0065)			
Economic					-0.0393** (0.0180)		
Unilateral						-0.0215 (0.0210)	
Plurilateral							-0.0590 (0.0411)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1377	1377	1377	1377	1377	1377	1377
R-squared (adjusted)	0.0724	0.0708	0.0714	0.0703	0.0730	0.0704	0.0737

p<0.01***, p<0.01*.
The values in parentheses denote the standard errors. All right-hand-side-variables are lagged by one year.
** p<0.05,

Table A31
PCSE Regression Analysis of Sanctions Impact on Measles Immunization Rates Among One-Year-Olds in 76 Target Countries

Measles	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
US Sanctions	-0.0473*** (0.0182)						
EU Sanctions		-0.0287** (0.0141)					
UN Sanctions			-0.0400** (0.0199)				
Intensity				-0.0146*** (0.0052)			
Economic					-0.0458** (0.0194)		
Unilateral						-0.0514** (0.0206)	
Plurilateral							0.0009 (0.0223)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1377	1377	1377	1377	1377	1377	1377
R-squared (adjusted)	0.1965	0.1869	0.1856	0.1934	0.1963	0.1976	0.1825

p<0.01*.
The values in parentheses denote the standard errors. All right-hand-side-variables are lagged by one year.
** p<0.05
*** p<0.01

Table A32
PCSE Regression Analysis of Sanctions Impact on Polio Immunization Rates Among One-Year-Olds in 76 Target Countries

Polio	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
US Sanctions	-0.0155 (0.0205)						
EU Sanctions		-0.0450*** (0.0119)					
UN Sanctions			-0.0048 (0.0420)				
Intensity				-0.0096** (0.0048)			
Economic					-0.0331* (0.0176)		
Unilateral						-0.0321* (0.0182)	
Plurilateral							-0.0415* (0.0238)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1378	1378	1378	1378	1378	1378	1378
R-squared (adjusted)	0.1598	0.1700	0.1582	0.1634	0.1662	0.1646	0.1644

The values in parentheses denote the standard errors. All right-hand-side-variables are lagged by one year.
* p<0.01.
** p<0.05,
*** p<0.01,

Table A33
Second-Stage Results of 2SLS Regression Analysis of Sanctions Impact on DPT Immunization Rates Among One-Year-Olds in 76 Target Countries (Using UNGA Instrument)

DPT	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
US Sanctions	-0.4953*** (0.1207)						
EU Sanctions		-1.5784*** (0.3540)					
UN Sanctions			-0.9777*** (0.1468)				
Intensity				-0.1582*** (0.0241)			
Economic					-0.3841*** (0.0751)		
Unilateral						-3.5724** (1.5001)	
Plurilateral							-0.4436 (1.8820)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1328	1328	1328	1328	1328	1328	1328
R-squared (adjusted)	0.3182	0.6939	0.3589	0.3180	0.2820	0.2582	0.3360

p<0.01*.
The values in parentheses denote the standard errors. All right-hand-side-variables are lagged by one year.
** p<0.05,
*** p<0.01,

Table A34
Second-Stage Results of 2SLS Regression Analysis of Sanctions Impact on Hepatitis B Immunization Rates Among One-Year-Olds in 76 Target Countries (Using UNGA Instrument)

HepB	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
US Sanctions	-0.1394 (0.0959)						
EU Sanctions		-1.8233*** (0.6151)					
UN Sanctions			-0.8054*** (0.1594)				
Intensity				-0.0729*** (0.0258)			
Economic					0.0033 (0.0743)		
Unilateral						-0.7073 (.0534)	
Plurilateral							0.2737 (0.3530)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1111	1111	1111	1111	1111	1111	1111
R-squared (adjusted)	0.0762	0.5030	0.3580	0.2990	0.1278	0.5666	0.5436

p<0.05**, p<0.01*.
The values in parentheses denote the standard errors. All right-hand-side-variables are lagged by one year.
*** p<0.01,

Table A35
Second-Stage Results of 2SLS Regression Analysis of Sanctions Impact on Measles Immunization Rates Among One-Year-Olds in 76 Target Countries (Using UNGA Instrument)

Measles	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
US Sanctions	-0.5256***						
	(0.1180)						
EU Sanctions		-1.4525***					
		(0.3224)					
UN Sanctions			-0.9464***				
			(0.1372)				
Intensity				-0.1561***			
				(0.0226)			
Economic					-0.4008***		
					(0.0712)		
Unilateral						-3.1701**	
						(1.3229)	
Plurilateral							0.2057
							(0.5920)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1328	1328	1328	1328	1328	1328	1328
R-squared (adjusted)	0.3108	0.6321	0.3356	0.2980	0.2673	0.1096	0.1191

p<0.01*.
The values in parentheses denote the standard errors. All right-hand-side-variables are lagged by one year.
** p<0.05,
*** p<0.01,

Table A36
Second-Stage Results of 2SLS Regression Analysis of Sanctions Impact on Polio Immunization Rates Among One-Year-Olds in 76 Target Countries (Using UNGA Instrument)

Polio	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
US Sanctions	-0.5296***						
	(0.1217)						
EU Sanctions		-1.5667***					
		(0.3915)					
UN Sanctions			-0.9650***				
			(0.1379)				
Intensity				-0.1555***			
				(0.0227)			
Economic					-0.4043***		
					(0.0733)		
Unilateral						-3.0760**	
						(1.3349)	
Plurilateral							0.3622
							(0.6045)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1386	1386	1386	1386	1386	1386	1386
R-squared (adjusted)	0.3055	0.6782	0.3365	0.2907	0.2596	0.1806	0.0761

p<0.01*.
The values in parentheses denote the standard errors. All right-hand-side-variables are lagged by one year.
** p<0.05,
*** p<0.01,

Table A37
Second-Stage Results of 2SLS Regression Analysis of Sanctions Impact on DPT Immunization Rates Among One-Year-Olds in 76 Target Countries (Using UNSC Instrument)

DPT	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
US Sanctions	-1.0942***						
	(0.2315)						
EU Sanctions		-0.9858***					
		(0.2461)					
UN Sanctions			-0.8988***				
			(0.1427)				
Intensity				-0.1896***			
				(0.0275)			

(continued on next page)

Table A37 (*continued*)

DPT	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Economic					-0.8160***		
					(0.1351)		
Unilateral						-1.9818***	
						(0.6757)	
Plurilateral							0.5215
							(.5408)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1282	1282	1282	1282	1282	1282	1282
R-squared (adjusted)	0.5205	0.4704	0.3478	0.3534	0.4189	0.7051	0.0467

p<0.05**, p<0.01*.
The values in parentheses denote the standard errors. All right-hand-side-variables are lagged by one year.
*** p<0.01,

Table A38
Second-Stage Results of 2SLS Regression Analysis of Sanctions Impact on Hepatitis B Immunization Rates Among One-Year-Olds in 76 Target Countries (Using UNSC Instrument)

HepB	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
US Sanctions	-0.6870***						
	(0.1659)						
EU Sanctions		-0.6601**					
		(0.2698)					
UN Sanctions			-.6322***				
			(0.1452)				
Intensity				-0.1487***			
				(0.0324)			
Economic					-0.6817***		
					(0.1581)		
Unilateral						-2.1970**	
						(1.0519)	
Plurilateral							0.9219
							(0.7868)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1053	1053	1053	1053	1053	1053	1053
R-squared (adjusted)	0.4062	0.3926	0.3350	0.3540	0.4051	0.7819	0.2097

p<0.01*.
The values in parentheses denote the standard errors. All right-hand-side-variables are lagged by one year.
** p<0.05
*** p<0.01

Table A39
Second-Stage Results of 2SLS Regression Analysis of Sanctions Impact on Measles Immunization Rates Among One-Year-Olds in 76 Target Countries (Using UNSC Instrument)

Measles	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
US Sanctions	-1.0452***						
	(0.2175)						
EU Sanctions		-0.9606***					
		(0.2327)					
UN Sanctions			-0.8667***				
			(0.1330)				
Intensity				-0.1813***			
				(0.0254)			
Economic					-0.7772***		
					(0.1253)		
Unilateral						-1.8100***	
						(0.6087)	
Plurilateral							0.3151
							(.4483)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1282	1282	1282	1282	1282	1282	1282
R-squared (adjusted)	0.4891	0.4448	0.3243	0.3272	0.3884	0.6352	0.2269

p<0.05**, p<0.01*.
The values in parentheses denote the standard errors. All right-hand-side-variables are lagged by one year.
*** p<0.01,

Table A40
Second-Stage Results of 2SLS Regression Analysis of Sanctions Impact on Polio Immunization Rates Among One-Year-Olds in 76 Target Countries (Using UNSC Instrument)

Polio	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
US Sanctions	-1.0753*** (0.2352)						
EU Sanctions		-1.0270*** (0.2782)					
UN Sanctions			-0.8566*** (0.1296)				
Intensity				-0.1828*** (0.0258)			
Economic					-0.8194*** (0.1399)		
Unilateral						-1.9311*** (0.7137)	
Plurilateral							1.0563 (1.3164)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1280	1280	1280	1280	1280	1280	1280
R-squared (adjusted)	0.4979	0.4667	0.3173	0.3226	0 4004	0.6770	0.3244

p<0.05**, p<0.01*.
The values in parentheses denote the standard errors. All right-hand-side-variables are lagged by one year.
*** p<0.01

Table A41
System GMM Analysis of Sanctions Impact on DPT Immunization Rates Among One-Year-Olds in 76 Target Countries

DPT	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
L.DPT	0.0511* (0.0280)	0.0539* (0.0280)	0.0532* (0.0280)	0.0530* (0.0280)	0.0522* (0.0279)	0.0473* (0.0280)	0.0531* (0.0280)
US Sanctions	-0.0264** (0.0110)						
EU Sanctions		-0.0230* (0.0137)					
UN Sanctions			0.0279 (0.0250)				
Intensity				-0.0120*** (0.0043)			
Economic					-0.0417*** (0.0126)		
Unilateral						-0.0535*** (0.0125)	
Plurilateral							0.0049 (0.0162)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1210	1210	1210	1210	1210	1210	1210
AR(2) p-value	0.9380	0.9960	0.9880	0.9500	0.9530	0.8500	0.9960

The values in parentheses denote the standard errors.
* p<0.01.
** p<0.05
*** p<0.01

Table A42
System GMM of sanctions affecting HepB immunization among 1-years-old population in the 76 target countries.

HepB	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
L.HepB	-0.0283 (0.0270)	-0.0266 (0.0270)	-0.0289 (0.0270)	-0.0293 (0.0271)	-0.0280 (0.0270)	-0.0289 (0.0270)	-0.0284 (0.0270)
US Sanctions	-0.0017 (0.0128)						
EU Sanctions		0.0183 (0.0147)					
UN Sanctions			0.0183 (0.0250)				
Intensity				-0.0019 (0.0049)			
Economic					-0.0029 (0.0141)		

(continued on next page)

Table A42 (*continued*)

HepB	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Unilateral						-0.0353* (0.0136)	
Plurilateral							0.0130 (0.0174)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	978	978	978	978	978	978	978
AR(2) p-value	0.4330	0.4600	0.4740	0.4120	0.4360	0.4660	0.4320

p<0.01***, p<0.05**,
The values in parentheses denote the standard errors.
* p<0.01.

Table A43
System GMM Analysis of Sanctions Impact on Measles Immunization Rates Among One-Year-Olds in 76 Target Countries

Measles	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
L.Measles	0.0557* (0.0286)	0.0599** (0.0285)	0.0596** (0.0285)	0.0583** (0.0286)	0.0567** (0 0285)	0.0518* (0.0286)	0.0595** (0.0286)
US Sanctions	-0.0234** (0.0092)						
EU Sanctions		-0.0046 (0.0114)					
UN Sanctions			0.0358 (0.0210)				
Intensity				-0.0076** (0.0036)			
Economic					-0.0251** (0.0106)		
Unilateral						-0.0366*** (0.0105)	
Plurilateral							0.0049 (0.0136)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1210	1210	1210	1210	1210	1210	1210
AR(2) p-value	0.1350	0.1660	0.1550	0.1480	0.1380	0.1080	0.1630

The values in parentheses denote the standard errors.
* p<0.01
** p<0.05,
*** p<0.01,

Table A44
System GMM Analysis of Sanctions Impact on Polio Immunization Rates Among One-Year-Olds in 76 Target Countries

Polio	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
L.Polio	-0.1175*** (0.0285)	-0.1160*** (0.0285)	-0.1212*** (0.0285)	-0.1167*** (0.0285)	-0.1187*** (0.0285)	-0.1243*** (0.0285)	-0.1185*** (0.0285)
US Sanctions	-0.0133 (0.0103)						
EU Sanctions		-0.0212* (0.0124)					
UN Sanctions			0.0373 (0.0229)				
Intensity				-0.0090** (0.0039)			
Economic					-0.0262** (0.0115)		
Unilateral						-0.0448*** (0.0113)	
Plurilateral							0.0001 (0.0148)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1210	1210	1210	1210	1210	1210	1210
AR(2) p-value	0.6790	0.7030	0.7040	0.7050	0.7480	0.8460	0.6790

The values in parentheses denote the standard errors.
* p<0.01.
** p<0.05,
*** p<0.01,

Table A45
Description of the 76 Developing Countries Experiencing International Sanctions from 2000 to 2019

Country	US^	EU^	UN^	Intensity*	Economic^	Unilateral^	Plurilateral^
Afghanistan	9	9	20	3.55	20	0	0
Algeria	0	0	0	0	0	0	0
Azerbaijan	3	0	0	0.45	3	3	0
Belarus	16	17	0	2.8	11	8	12
Belize	14	5	0	0.7	9	9	5
Benin	3	9	0	0.75	3	12	0
Bolivia	9	0	0	0.45	9	9	0
Bosnia and Herzegovina	0	16	0	2.05	7	16	0
Burkina Faso	2	0	0	0.3	2	2	0
Burma (Myanmar)	19	19	0	3.55	11	1	19
Burundi	11	5	0	1.65	11	6	5
Cambodia	1	2	0	0.45	1	3	0
Cameroon	4	0	0	0.6	4	4	0
Central African Republic	11	3	0	1.65	8	8	3
Chad	2	0	0	0.1	2	2	0
China	20	20	0	2	20	0	20
Colombia	0	0	0	0	0	0	0
Comoros	0	1	0	0.15	1	1	0
Croatia	0	1	1	0.1	1	0	0
Cuba	20	3	0	5	20	17	3
Democratic Republic of the Congo	14	20	17	2	20	0	3
Egypt	5	9	0	0.75	9	4	5
El Salvador	1	0	0	0.15	1	1	0
Equatorial Guinea	0	20	0	3	20	20	0
Eritrea	5	8	12	1.5	15	3	0
Ethiopia	0	0	2	0.2	2	0	0
Fiji	5	8	0	1.2	8	3	5
Gambia	4	7	0	1.35	9	9	2
Guatemala	9	0	0	1.35	0.45	9	0
Guinea	6	13	0	0.95	10	9	4
Guinea-Bissau	4	0	6	0.55	9	4	0
Haiti	7	5	0	1.1	7	2	5
Honduras	2	2	0	0.3	2	0	2
Indonesia	6	0	0	0.6	6	6	0
Iran	20	0	5	5	20	6	0
Iraq	4	0	4	1	0	0	0
Ivory Coast	15	15	13	3.05	17	0	3
Jamaica	0	0	0	0	0	0	0
Jordan	0	0	0	0	0	0	0
Kenya	0	0	3	0.3	3	0	0
Laos	2	0	0	2	2	2	0
Lebanon	13	14	15	1.5	0.75	0	0
Liberia	12	1	16	2.5	3	0	0
Libya	20	14	12	4	20	0	0
Madagascar	7	8	0	1.2	8	1	7
Malawi	0	0	0	0	0	0	0
Mali	3	2	3	0.55	2	0	2
Mauritania	2	2	0	0.3	2	0	2
Nicaragua	2	0	0	0.3	2	2	0
Niger	4	3	0	0.65	0	1	3
Nigeria	0	0	0	0	0	0	0
North Korea	20	14	14	5	0	6	0
North Macedonia	1	0	0	0.1	1	0	1
Pakistan	6	0	0	0.9	0	6	0
Peru	0	2	0	0.3	2	2	0
Republic of the Congo	2	0	0	0.1	2	2	0
Russia	6	6	0	1.2	6	0	6
Rwanda	2	1	0	0.1	0	2	1
Serbia	4	20	2	1.6	4	18	0
Sierra Leone	3	11	11	0.7	0	3	0
Somalia	20	18	20	3	20	0	0
South Africa	0	0	0	0	0	0	0
Sri Lanka	1	0	0	0.1	1	1	0
Sudan	20	20	20	3	1	0	0
Syria	20	20	3	3.75	20	0	17
Thailand	4	4	0	0.4	4	0	4
Togo	0	5	0	0.75	5	5	0
Tunisia	0	9	0	0.4	9	9	0
Turkey	1	1	0	0.1	0	0	0
Ukraine	1	1	0	0.05	1	0	0
Uzbekistan	13	5	0	1.3	5	8	5
Venezuela	14	3	0	2.4	14	11	3
Vietnam	0	0	0	0	0	0	0
Yemen	9	5	2	1.35	7	3	4
Zambia	0	0	0	0	0	0	0
Zimbabwe	18	18	0	3.6	18	0	18

^ The number of years from 2000 to 2019 during which the country experienced a specific type of sanctions.
* The average intensity of international sanctions imposed on the country between 2000 and 2019.

Table A46
List of the 45 Control Countries for Regression Analysis in Tables A21 to A24

Albania	Cape Verde	Guyana	Mongolia	Romania
Angola	Chile	India	Morocco	Saudi Arabia
Argentina	Comoros	Kazakhstan	Mozambique	Senegal
Armenia	Croatia	Lesotho	Namibia	Tajikistan
Bahrain	Dominican Republic	Liberia	Nepal	Tanzania
Bangladesh	Ecuador	Malaysia	Paraguay	Trinidad and Tobago
Botswana	Gabon	Mauritius	Philippines	Uganda
Brazil	Georgia	Mexico	Poland	United Arab Emirates
Bulgaria	Ghana	Moldova	Qatar	Uruguay

Data availability

Data will be made available on request.

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