A Commitment to Vaccination Index

Measuring Government Progress toward Global Immunization

Amanda Glassman, Juan Ignacio Zoloa, and Denizhan Duran

Abstract

Vaccination is among the most cost-effective health interventions and has attracted ever greater levels of investment from public and private funders. However, some countries, mainly populous lower-middle-income countries, are lagging behind in vaccination financing and performance.

In this paper, we discuss the rationale for investing in vaccination and construct a metric to measure country commitment to vaccination that would promote accountability and better tracking of performance.

Conceding data limitations, we find that populous middle-income countries, which stand to gain tremendously from increased vaccination uptake, perform poorly in terms of their vaccination outcomes and that donors may also benefit from higher marginal returns in these countries.

Amanda Glassman, Juan Ignacio Zoloa, and Denizhan Duran. 2012. "Measuring Government Commitment to Vaccination." CGD Policy Paper 008. Washington DC: Center for Global Development.
http://www.cgdev.org/content/publications/detail/1426396

CGD is grateful for contributions from the UK Department for International Development in support of this work.

Center for Global Development
1800 Massachusetts Ave NW
Third Floor
Washington DC 20036
202-416-4000
www.cgdev.org

Center for Global Development

CGD Policy Paper 009
August 2012

Contents

I. Introduction

Vaccines are often described as one of the most cost-effective interventions to improve health outcomes among the world's poorest, as they have saved the lives of more children than any other medical intervention in the last 50 years. Vaccination is expected to remain a cost-effective investment, as newer vaccines are also thought to be cost-effective: there have been studies deeming the Hepatitis B, rotavirus, Hib and pneumococcal vaccines as cost-effective.[1] A 2006 study estimates the return of increased vaccination to be 18% by 2020.[2] If vaccine delivery expands at its current pace, by 2020, 6.4 million premature deaths could be averted, which could yield financial returns of $231 billion – most of these savings would come from populous lower-middle income countries such as India (Ozawa et al 2011). All of this is possible with a cost of $38.80 per unvaccinated child, according to the latest WHO estimates (Medecins Sans Frontieres, 2012). [3]

Given these arguments, vaccines have attracted significant investment: this decade has been declared as the Decade of Vaccines, and many donors have pledged increased funding to vaccination. While much progress has been made, current levels of investment are not enough to eradicate vaccine-preventable diseases, given the fact that 23 million children in developing countries (or, one out of five children) still do not receive life-saving vaccines. This is in part due to a lag between the introduction of vaccines in low and high-income countries: private investors lack the incentives to introduce vaccines in low-income settings.[4] Much of this investment is also due to the Millennium Development Goal 4; the reduction of under-five mortality by two thirds until 2015.

The efforts of the Decade of Vaccines are embodied in the establishment of GAVI Alliance, which brings a "single-minded focus" to vaccination investment by pooling in resources from bilateral donors, WHO, UNICEF, World Bank, and the Bill and Melinda Gates Foundation. GAVI mostly works in low-income countries, and defines eligibility by a threshold of $1,500. As a public-private partnership, GAVI seeks to get immunization on the agenda, make vaccines affordable, secure predictable financing and foster country ownership. Despite the plateauing investment in global health, GAVI was able to attract an additional £2.6bn in 2011.[5]

The sustained investment in GAVI also reflects that the benefits of vaccination can be thought of as a global public good. Communicable diseases are easily spread across borders

---

[1] "GAVI Alliance: Cost-effective" http://www.gavialliance.org/about/value/cost-effective/ Accessed 2/22/2012

[2] "Harvard School of Public Health Study Finds Vaccines Boost the Economies of Poor Countries" October 14, 2005. http://www.hsph.harvard.edu/news/press-releases/archives/2005-releases/press10142005.html Accessed 2/22/2012

[3] Includes 1BCG, 3 oral polio vaccine, 3 DRP, 2 measles, Hep B, Hib, PCV, rotavirus and rubella

[4] "GAVI Alliance: What we do" http://www.gavialliance.org/about/mission/what/ Accessed 2/22/2012

[5] "Vaccine funding: rich countries, led by Britain, to give additional £2.6bn" Maev Kennedy and Sarah Boseley, June 2011. http://www.guardian.co.uk/society/2011/jun/13/vaccine-funding-uk-gives-814m

and imported vaccine-preventable disease outbreaks are common and costly, even in the wealthiest countries of the world (Dollar, 2001).

Given these arguments, vaccines have attracted significant funding: this decade has been declared the Decade of Vaccines, and many donors have pledged increased monies to vaccination efforts. While much progress has been made, current levels of funding are not enough to fully control or eradicate vaccine-preventable diseases, given that 23 million children in developing countries (or, one out of five children) still do not receive a full course of WHO-recommended vaccines (Shot at Life, 2012).

Beyond the goal of eradicating or eliminating vaccine-preventable diseases such as polio, the main objective of most international efforts is to increase vaccination coverage such that herd immunity from disease and a herd effect on the unimmunized are attained.[6] While there is no certain level of herd immunity due to geographic variation in the epidemiology of the relevant disease and the efficacy of the vaccine, estimates put the lower bound between 75% - 90% for most vaccine preventable diseases (Fine, 1993; see table 1). As country borders are porous and globalization and urbanization imply growing population mobility, achieving herd immunity and the associated herd effect at the global level requires a long-lasting, coordinated and global commitment and action, and can be thought of as a "global public good."

Table 1. Various vaccine preventable diseases and herd immunity rates (Fine, 1993)

Infection	Herd immunity rate (%)
Diphtheria	85
Malaria	80-99
Measles	83-94
Mumps	75-86
Pertussis	92-94
Polio	80-86
Rubella	83-85
Smallpox	80-85

All of these factors increase the stakes for vaccination and necessitate contribution from every country, yet current tracking of vaccination performance falls short of the information needed to motivate increased and stable commitment. There are discrepancies between the World Health Organization's administrative data and Demographic and Household Survey (DHS) data, for example, and in many cases survey data yields lower rates than administrative data. WHO and UNICEF have a Joint Reporting Process (JRP), which seeks

[6] John and Samuel (2000) define herd immunity as "the proportion of subjects with immunity in a given population" and herd effect as "the reduction of infection or disease in the unimmunized segment as a result of immunizing a proportion of the population"

to streamline reporting of vaccine expenditures by each country. While it is a valuable resource, its scope is limited given the fact that it relies mainly on administrative data, many countries do not report, and it is infrequently updated. Further, there is no study that seeks to comprehensively track country progress and keep countries accountable for investing in public health.

To fill this gap, in this paper, we develop an index to measure countries' contributions to vaccination as a global public good. The index is not intended to replace official estimates of vaccination performance; indeed the index depends on these measures. We hope instead that the attempt to define and expand measures of performance can focus attention on the determinants of such performance, on the role of each country's government in achieving global vaccination-related goals, and on improving the quality and scope of statistical data on vaccination program performance.

We start by describing the rationale for investment in vaccination as a global public good, describe candidate measures' strengths and weaknesses, propose a composite index and discuss our results.

II. Dimensions of Vaccination as a Global Public Good

Global public goods (GPG) in health are programs, policies and services that have a truly global impact on health, although the distribution of benefits may be unevenly experienced or perceived across countries (WHO Commission on Macroeconomics, 2002). GPG are non-rivalrous –the marginal cost of providing them is zero – and non-exclusive – people cannot be prevented from consuming it. Since these goods involve cross-border externalities, they are bound to be undersupplied as countries will tend to free-ride: if country X chooses to research communicable disease prevention and country Y chooses not to, country Y will still benefit from the information produced by country X.

Today, global public goods in health are more relevant than ever. The rapid pace of globalization and interdependence has implications for travel, technology and trade and thus has spillover effects for health. Communicable diseases are transmitted across borders very rapidly, some more so than others. While many communicable diseases have been eliminated in higher-income countries, it is very easy to lose ground: recently, there have been historic numbers of measles cases in Europe, and Europe's failure to vaccinate threatens the United States and Latin America as well.[7]

The World Health Organization's Commission on Macroeconomics and Health has identified three aspects of global health that fall into categories of global public goods: basic and applied research and targeted R&D, prevention and control of cross-border spread of

[7]Victoria Fan, "Europe's Unwelcome Export: Measles" http://blogs.cgdev.org/globalhealth/2011/12/europe%E2%80%99s-unwelcome-export-measles.php

communicable disease, and standardized data collection for analysis. In our paper, we frame vaccination as a global public good in terms of all three aspects.

Historically, countries and industry have had little incentive to invest in global public goods, given the free rider problem described above. The past decade in vaccination has proven an exception to this trend. Significant progress has been made with the establishment and growth of the GAVI Alliance, an organization funding vaccines in countries with an average income per capita below $1,500. GAVI sponsored the pneumococcal advanced market commitment (AMC) mechanism, in which donors commit to guarantee the price of vaccines once they have been developed and manufacturers sell the vaccines to developing countries in an affordable price. GAVI also operates IFFIm, the International Finance Facility for Immunization, which sells vaccine bonds to make smoothed funds available to GAVI programs, thus increasing predictability in vaccine investment. As GAVI has worked in 76[8] countries, its work in increasing vaccination rates has spillover effects across borders.

In the next section we look at vaccination as it pertains to the framing of global public goods.

Basic and applied research and targeted R&D

Knowledge is a global public good and sustaining research in (any) country has global ramifications (Freeman and Miller 2001). Research is a fundamental part of vaccine development, and embodies the typical free-rider issue inherent in global public goods: research by pharmaceutical companies often focuses on rich-world diseases where markets are large, as the potential for profitability in poor countries is lower. This constitutes a crucial problem, however, as there is a very large gap between disease burden and public health spending. This is particularly apparent in communicable diseases, many of which are vaccine preventable. The G-FINDER (Global Funding of Innovation for Neglected Diseases) report (2011) indicates that despite the fact that research and development on neglected

[8]The number of GAVI eligible countries has fallen from 76 to 57, as GDP per capita of countries rose above the $1,500 threshold. Since its inception, GAVI has worked at the following countries: Afghanistan, Albania, Angola, Armenia, Azerbaijan, Bangladesh, Benin, Bhutan, Bolivia, Bosnia and Herzegovina, Burkina Faso, Burundi, Cambodia, Cameroon, Central African Republic, Chad, China, Comoros, Congo, Democratic Republic of the Congo, Côte d'Ivoire, Cuba, Djibouti, Eritrea, Ethiopia, Gambia, Georgia, Ghana, Guinea, Guinea-Bissau, Guyana, Haiti, Honduras, India, Indonesia, Kenya, Kiribati, Democratic People's Republic of Korea, Kyrgyzstan, Lao People's Democratic Republic, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Republic of Moldova, Mongolia, Mozambique, Myanmar, Nepal, Nicaragua, Niger, Nigeria, Pakistan, Papua New Guinea, Rwanda, Senegal, Sierra Leone, Sao Tome and Principe, Solomon Islands, Somalia, Sri Lanka, Sudan, Tajikistan, United Republic of Tanzania, Timor-Leste, Togo, Turkmenistan, Uganda, Ukraine, Uzbekistan, Viet Nam, Yemen, Zambia & Zimbabwe.

diseases[9] is a global public good, global spending on R&D for neglected diseases decreased by 3.5% to $3 billion from 2009 to 2010, 65% of which came from public funders.

The main reason that investment in vaccine research and development is not high is the relative lack of market incentives, as well as very high upfront costs. Yet given that vaccination is a global public good and that achieving herd immunity is essential for eradication, investment in vaccine research and development is pivotal.

It is possible to overcome the issue of free-ridership and incentives, however. Product Development Public-Private Partnerships (PDPs) have demonstrated the potential for this: PDPs accelerate the research and development of pharmaceuticals that are particularly geared towards diseases seen in low- and middle-income countries. They resolve the incentive and financial barrier problems by bridging public and private sector interests: each PDP manages a portfolio of product candidates within their own product niches, expands the product pipeline by rapidly advancing promising approaches. PDPs to new drugs now manage 75% of all identified neglected disease drug development projects, and are helping advance drugs for various other diseases as well. The International AIDS Vaccine Initiative is an example of an efficient PDP, which has mobilized more than $460 million in funding vaccine research.[10]

Expanding the market for vaccines has proven to be successful with previous efforts such as the Advance Market Commitments (AMC) and the International Finance Facility for Immunization (IFFIm). The idea of an AMC for vaccines first gained popularity with a Center for Global Development report in 2005, "Making Markets for Vaccines: Ideas for Action." (Levine et al 2005). The report finds that instead of incentivizing vaccine development through prizes, making markets would provide a more sustainable source for incentives: structured correctly, an AMC would ensure a future supply of vaccines. In an AMC, donors would commit to providing a sum of money if a vaccine is developed, so if the vaccine is not developed there would be no cost to donors. This benefits donors given the low risk associated with the commitment, the industry given the risk-reward structure and the developing countries since it accelerates the development and distribution of new vaccines. The prominence of various Product Development Partnerships and AMC shows that it is possible to overcome the issue of free-riding in knowledge.

---

[9] The term neglected disease is used to refer to developing country diseases that have a low incidence in the high-income countries or have different disease profiles when occurring in developing countries. These factors have led to a lack of R&D investment in developing-country specific product development. The following diseases are generally considered "neglected diseases": HIV/AIDS, Malaria, TB, Kinetoplastids, Diarrhoeal, Salmonella infections, Dengue, Helminths, Bacterial Pneumonia & Meningitis, Leprosy, Buruli Ulcer, Trachoma & Rheumatic Fever.

[10] "Product Development Public-Private Partnerships (PDPs)." http://www.iavi.org/Lists/IAVIPublications/attachments/fcc09677-ae07-436c-b194-0fc08a9cdb64/IAVI_PDP_2006_ENG.pdf Accessed 2/27/2012

Many studies point out to the positive impact of global health R&D for developed countries: a report by the Global Health Technologies Coalition shows that funding global health R&D brings tremendous economic benefits to the US government, which is the largest funder and has spent around $1.2 billion every year for the past decade. The report points out to areas where the US has led, such as developing the meningitis A vaccine, a new TB diagnostic, an HIV vaccine candidate and a new TB drug regimen. Investing in global health R&D has positive implications for the economic well-being and national security of developed countries, and countries need to scale up investment.

While countries do contribute to vaccine R&D, the level of contribution is often far below the desired level. A study from 2009 shows that low- and middle-income countries are not able to fund their own R&D programs: between 1998 and 2005, low- and middle-income countries increased spending on health research by 42%, but their contribution still amounted to 3% of the global health research budget in 2005 (Schneegans 2008). There have been attempts to increase this spending: in 2008, the Bamako Call to Action was agreed by 62 countries which committed to spend 2% of their public health budgets on research. Yet, many countries, particularly low- and lower-middle income countries, are lagging behind in committing to research and development, which makes contributions from high-income countries more important.

Cross-border spread of communicable disease

The WHO's Report on Global Public Goods cites disease eradication as the "purest of global public goods," as once it is achieved it is both non-excludable and non-rivalrous (WHO, 2002). The eradication of smallpox has been estimated to save 30 million lives and US$25 million every year for 12 years since 1979. This eradication effort has also been proven to be cost-effective, as cumulative savings were calculated as being over US $168 billion. Yet, not all eradication is cost-effective. Currently, there are eradication initiatives for polio and guinea worm eradication, and the International Task Force for Disease Eradication defined measles, rubella, cysticercosis, lymphatic filariasis and mumps as potential eradication candidates (Dowdle and Cochi 2011). However, any discussion of eradication involves benefit-cost analyses that involve looking at the economic conditions, political will, other immunization priorities as well as the current phase of the disease. Even if eradication is not reached, scaling up investment proves to be a cost-effective investment: Ozawa et al (2011) show that 6.4 million deaths can be averted between 2011 and 2020 by scaling up vaccine delivery in 72 low- and middle-income countries, which would amount to an economic benefit of $231 billion.

Economic modeling suggests that international coordination and co-financing can be important for elimination and eradication. Recent work by Klepac et al (2011) shows that when borders across communities and countries are highly porous ("strongly coupled"), asymmetries in costs can lead to divergent control optima, with the result that "strong regional differences in costs of vaccination can preclude local elimination even when

elimination is locally optimal." Under certain conditions, therefore, it is locally optimal to share vaccination resources with or lower costs to other populations. Coupled with porous borders and immigration, the burden of each additional infection exceeds the cost, pointing out to the need for sustained investment. This inter-connectedness also promotes free-riding in vaccination efforts between populations and results in lower levels of vaccination in each subpopulation relative to the global optimum. Given this, it is important to pool resources together, especially for neighboring communities, to ensure herd immunity: India, for example, would benefit from supporting vaccination efforts in Pakistan, Bangladesh or Nepal as much as it would benefit from increased uptake within its own borders. This shows that achieving vaccination levels close to herd immunity is a global public good.

The eradication of polio is the next frontier in vaccine preventable disease eradication, and has initially relied on a public-private partnership between the US Centers for Disease Control and Prevention (CDC), WHO and Rotary International. At the end of 2002, polio was endemic in seven countries (Acharya et al 2003); now it is down to four: Afghanistan, Nigeria, Pakistan, and until very recently India. Given this, the Global Polio Eradication Initiative's funding resources have also changed tremendously: currently, the largest public funder is India, and domestic resources contribute 23% of total funding compared with 17% by G8 countries and 29% by the private sector, with Bill and Melinda Gates Foundation being the largest funder. The 2011-2012 funding gap is currently at US$535m of a total budget of $2.23 billion. The Global Polio Eradication Initiative indicates that polio eradication makes economic sense as well, given the fact that polio control would yield benefits of $40-$50 billion, and that 8 million cases would be prevented through 2035. Given outbreaks in the Republic of the Congo and Tajikistan in 2010, scaling up investment is an economic and humanitarian task.

A fundamental problem with vaccination investment is that the country that contributes the least towards the desired outcome tends to set the level that is achievable as a collective – which is why preventing the cross-border transmission of communicable disease requires a "weakest link" approach. Further, the benefits of global vaccine-preventable disease control efforts will be greatest for countries that have already reduced or eradicated these diseases within their borders, as they would need to devote an additional number of resources to combat already prevented diseases. The marginal cost of combating an already eliminated disease is very high, as the case of malaria in Tanzania shows (WHO, 1999). A calculation by the United Nations shows that the United States recoups the costs incurred from smallpox eradication programs once every 26 days (Tenkorang and Conceicao 2003).

There has been significant progress in control of vaccine-preventable disease over the last decade; over 80% of all children in developing countries receive basic vaccinations. In 2008, average coverage of measles reached 81 percent in low- and middle-income countries, up from 70 percent in 2000. However, projections show that without sustained funding for immunization activities in priority countries, mortality from measles could rebound quickly, resulting in approximately 1.7 million measles related deaths between 2010 and 2013 (UN, 2010). It is therefore important to maintain this progress: herd immunity is necessary to

eliminate certain vaccine-preventable diseases as problems of public health significance, such as diphtheria, measles, mumps, pertussis, polio and rubella.[11]Assuring stable, predictable funding and support to national vaccination programs remains important to avoid cross-border outbreaks.

While progress is substantial, expert organizations point to continued funding gaps. The funding gap for measles elimination was estimated to be at US$392 million until the end of 2015 (Acharya, 2002). In the case of meningitis, the total requirement is US$570 million to end 2015 of which GAVI is set to finance US$ 369 million. The total requirement for yellow fever is US$ 65 million by end 2013 of which GAVI is set to finance US$ 271 million. For polio, the total requirement is US$ 2.1 billion by the end of 2013; the current funding gap stands at US$ 875 million.[12]

Given these arguments, we classify vaccine-preventable disease control and elimination as a global public good that relies on every country's adequate investment to ensure success. Long-term funding must be sustained for this goal, and every country must commit resources to ensure vaccination both within and outside of their borders. In the next section, we discuss candidate measures of vaccination program performance and develop an index which tracks country progress towards this goal.

Standardized data collection for analysis

Accurate and timely data collection and analysis is essential for quantifying progress in the global public goods of control, elimination and eradication of vaccine-preventable disease and is also necessary for informed policy and program design and management. In addition, the WHO classifies any kind of data collection effort – from simple descriptive statistics such as vital statistics or full immunization rates, to more detailed health system performance data or comprehensive demographic and health surveys (DHS) – as a global public good itself, since data and analysis from one context can inform the analysis and interpretation of data in other settings (WHO Commission on Macroeconomics and Health, 2002).

WHO and UNICEF have a Joint Reporting Process (JRP), which seeks to streamline reporting of vaccine coverage and financing by country. JRP is a valuable resource, yet its scope and relevance is limited given its reliance on government-reported administrative data, the extent of country non-reports, the absence of reporting standards on public expenditure data and infrequent updates (discussed in further detail below); as can be seen in the next section, many countries do not report to the JRP. However, JRP is still a valuable resource, and is used by GAVI for their immunization services support, and both GAVI and

[11]"History and Epidemiology of Global Smallpox Eradication" http://www.bt.cdc.gov/agent/smallpox/training/overview/pdf/eradicationhistory.pdf

[12]"Global Immunization Efforts, Successes, Gaps & Challenges" http://www.who.int/immunization/funding/GID_Meeting_NYC_20Feb09_revised.pdf

UNICEF use it to report various statistics in their annual publications (World Health Organization, 2005).

With greater use of data, more standardized guidance and supervision of data collection, and greater resources, JRP data could be used more systematically to comprehensively track country progress and keep countries accountable for vaccination results, and would represent a public good.

III. Building an Index of Vaccination Commitment

In this section, we discuss candidate indicators that could be used to measure every country's commitment to vaccination as a global public good. In this context, we define commitment as a function of performance and financing; as both good inputs and outputs. We use four dimensions to group the effort that each country makes towards global immunization:

1. Own Vaccination Performance
2. Own Vaccination Financing
3. Completeness of Vaccination Data
4. Fair Share Contributions to Global Vaccination Efforts

Dimension 1: Own Vaccination Performance

Countries' own commitment to vaccination is best captured by their performance within their own borders. Given this, our first dimension measures how countries fare within their borders.

The three indicators we include in this dimension are:

- **Last available year's DTP-3 vaccination rate (WHO):** While we concede that WHO/UNICEF data is not as reliable as survey data (see box 1), for the sake of consistency and availability we use the DTP-3 vaccination rate for 2010 as reported by WHO/UNICEF.
- **Stability in coverage once above 85%:** Once vaccination rates increase above a certain threshold, the rate of increase tends to taper off in both developed and developing country contexts.[13] Good performance can be defined as achieving and maintaining coverage rates necessary to assure herd immunity. This indicator measures the percentage of periods where a government reports more than 85% coverage of DTP-3 between 1980 and 2010.
- **Average coverage from 1980 to 2010 (WHO):** In this indicator we seek to look at the historical trend of country vaccination performance, looking at performance

[13]"Immunization Strategies for Healthcare Practices and Providers" http://www.cdc.gov/vaccines/pubs/pinkbook/downloads/strat.pdf.

across the last thirty years, to quantify historical commitment to vaccination performance.

Indicators that we would have ideally liked to include, but could not due to data limitations are:

- **Last available year's complete vaccination as measured by a household survey:** Although official statistics usually present a more optimistic picture of vaccination coverage, such statistics do not accurately represent the scale of the problem. In low- and middle-income country settings, household surveys report consistently and significantly lower vaccination rates compared to official rates by the World Health Organization. In an analysis of DTP3 coverage data, Lim et al (2008) find that administrative data tends to be upward biased given performance-based incentives and measurement errors (see box 1). Because household survey data is only available in a limited number of countries, we omit this indicator.
- **Effective coverage of vaccination as measured by immune response of a representative sample of children:** Effective coverage is a more holistic approach to evaluating vaccine effectiveness, and it takes into account the proportion of people who have received effective interventions.[14] Effective coverage looks at the potential health gain that can be delivered by that particular health intervention, and takes affordability, as well as impact on health inequalities, into account. Calculating the effective coverage of vaccination requires blood tests among a representative sample and this data is not available in most settings, so the indicator was omitted.
- **Rate of change in coverage:** The rate of coverage improvements is an indicator of country effort. In this indicator, we look at the rate of change in coverage in DTP3 vaccination from 1980 to 2010, by running a year fixed effects regression for every country. We omit this from our index given the fact that it is negatively correlated with having a high average vaccination rate, but report the rate on the appendix (see appendix 4).
- **Inequality in coverage:** While low- and middle-income countries have obtained high vaccination rates, the results are very different for various regions or communities within these countries. Household surveys in China and India demonstrate that the poorest usually have lower health status and report lower levels of utilization, including lower rates of vaccination. This data is only available from household surveys, which are not available for every country (see appendix 1).
- **Quality of vaccine-preventable disease surveillance:** Surveillance efforts are essential to prevent vaccine-preventable diseases or control outbreaks, and an ideal index would incorporate a measure of the completeness and quality of VPD

[14] "Draft Report of Technical Consultation on Effective Coverage in Health Systems" http://www.who.int/health-systems-performance/technical_consultations/effcov_report.pdf

surveillance. Yet, information on surveillance is hard to track down, and thus is omitted from our index.

- **Measures of "good policy":** Literature suggests policy features that are associated with better vaccination program performance– appropriately constituted National Immunization Technical Advisory Groups (NITAG); full vaccination required for school admission; vaccine safety measures; functioning NRA if vaccine manufacturers; procurement processes; etc. However, current global databases do not track or systematize the definition of "good policy," and these measures are therefore omitted from our analysis.

BOX 1. Data limitations on vaccination performance

It is important to note that there are three different ways vaccination performance outcomes are reported: administrative data, WHO/UNICEF data, and household survey data; all of which have limitations.

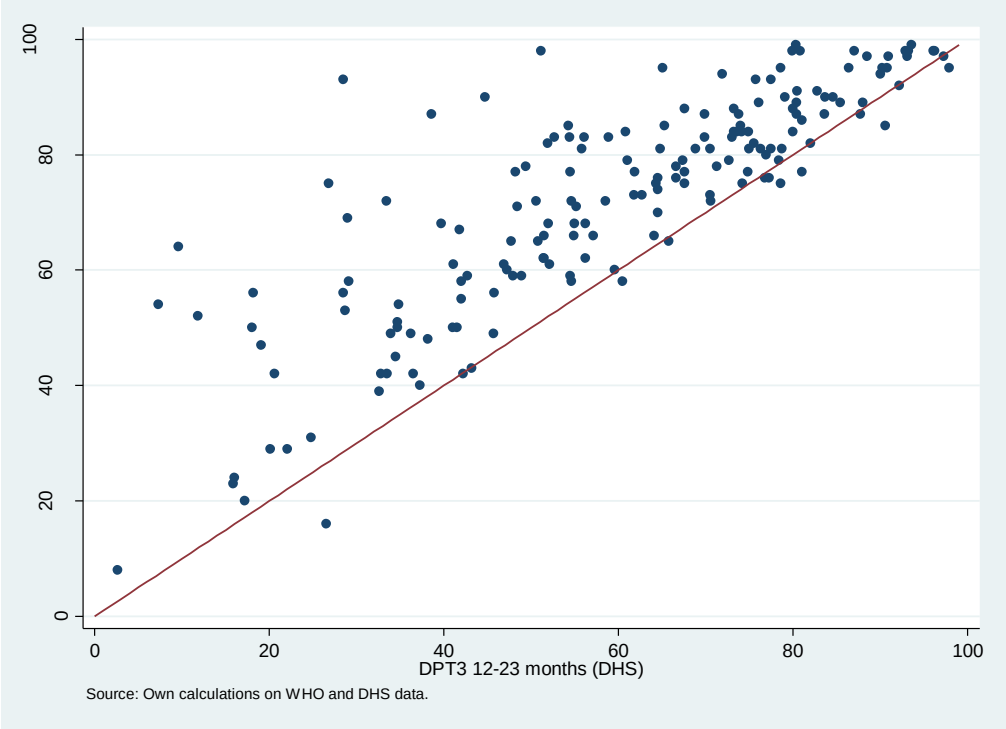
Administrative data are level estimates about immunization of the population. This estimate is obtained by dividing the total number of vaccines administered by governments by the number of children in the target population, which are often based on census projections. It is provided by country health service provider registries, and is prone to mistakes given weakness in data systems or incentives to over report given the performance-based immunization services support (ISS) payments. These estimates may also have problems in the amount of vaccines given, due to the possibility that governments misreport the dates or amounts of vaccines. It may also contain errors in the denominator because, in general, censuses are conducted every ten years, so the estimation of the target population in distant years from the date of the census could have large differences. As many countries lack vital registration systems, the validity of administrative data is questionable, despite adjustments by the WHO and UNICEF.

While GAVI uses this data to guide its disbursement decisions and cites its data quality audits as a good way to control for these issues, Lim et al (2008) find systematic over reporting of administrative data – up to an overestimation of four times in certain countries such as Pakistan. In the figure below, we plot the relationship between immunization data for DTP3 (WHO) and from surveys (Demographic and Health Surveys, DHS[*]). This shows that administrative data reported are systematically greater than those obtained from surveys.

* Macro International Inc, 2011. MEASURE DHS STATcompiler. http://www.measuredhs.com.

Note: While household survey data is more reliable, it is not available for every year and every country (see dimension 3), which is why we only report it and do not use it to compose our index. Given these limitations in performance data, we concede that the vaccination performance indicator is not as rigorous as it should be. Countries should invest more in vital registration systems, and GAVI should conduct more rigorous data quality audits and encourage household surveys.

Relationship between administrative data (WHO) and from surveys (DHS).



The figure above includes data for the period 1986 -2009 of Armenia, Bangladesh, Benin, Bolivia (Plurinational State of), Botswana, Brazil, Burkina Faso, Burundi, Cambodia, Cameroon, Chad, Colombia, Comoros, Congo, Côte d'Ivoire, Dominican Republic, Egypt, Eritrea, Ethiopia, Gabon, Ghana, Guatemala, Guinea, Haiti, Honduras, India, Indonesia, Jordan, Kazakhstan, Kenya, Kyrgyzstan, Lesotho, Liberia, Madagascar, Malawi, Maldives, Mali, Mauritania, Morocco, Mozambique, Namibia, Nepal, Nicaragua, Niger, Nigeria, Pakistan, Paraguay, Peru, Philippines, Republic of Moldova, Rwanda, Senegal, Sierra Leone, South Africa, Sri Lanka, Sudan, Swaziland, Thailand, Togo, Trinidad and Tobago, Tunisia, Turkey, Turkmenistan, Uganda, United Republic of Tanzania, Uzbekistan, Vietnam, Yemen, Zambia & Zimbabwe.

Dimension 2: Own Vaccination Financing

How immunization is financed is an important measure of country efforts in preventing diseases. Countries' own financing of vaccination programs is becoming more relevant as many countries graduate from GAVI support: it is projected that the number of GAVI-eligible countries will drop from 56 to 42 by 2020 (under its current eligibility rules); the population of infants who live in GAVI eligible countries is expected to decrease from 329 million to 156 million (Glassman et al 2011). Sufficient and timely financing is even more important, as national immunization programs rely on routine immunization which gives more sustained gains compared to intermittent campaigns: a recent case study shows that in three sub-Saharan African countries (Cameroon, Ethiopia and Ghana), commitment to routine immunization programs as opposed to intermittent campaigns was associated with higher immunization coverage (LaFond et al 2012).

Further, GAVI is moving towards increased co-financing requirements for lower-middle income countries. Saxenian et al (2011) analyze the fiscal space of GAVI eligible countries, finding that co-financing is almost impossible to achieve in low-income countries over the medium term, whereas lower-middle income countries can better absorb a co-financing amount of $0.20 per dose. Co-financing is a tool for country ownership, and to this end this dimension seeks to capture how committed countries are to increasing vaccination outcomes: a paper in 2008 showed that the share of government financing of routine immunization in low-income countries went up from 35% to 39% from 2000 to 2008 (Lydon et al 2008).

In this dimension, we look at how countries finance their own vaccination efforts, and our principal data source is the World Health Organization and UNICEF's Joint Reporting Process; which is incomplete because many countries do not report to it. Below are the indicators we have included for this dimension:

- **Share of vaccination budget funded by national government, 2009 (WHO):** Countries should have a budget enough to vaccinate entire eligible population each year in order to ensure herd immunity. The immunization process requires significant expenditures in order to purchase vaccines and injection supplies like syringes, needles, sharp boxes, etc. Given this, sufficient financing is crucial in order to vaccinate the entire target population.
- **Line item in national budget for purchase of vaccines and injection items, 2009 (WHO):** Committing to vaccination relies on stable budgeting, as disruptions in a given year endanger obtaining herd immunity. Given this, we look at whether countries have a budget line for vaccination, as well as trends in vaccination financing. Having a budget line item for vaccination is associated with higher vaccination spending (Lydon et al, 2008). Although there is a budget line for immunization, there are no guarantees that the disbursement of vaccines will take place. It is for this reason that we also focus on vaccines expenditure.
- **Vaccine spending per infant (WHO/WDI), 2009**[15]**:** This indicator measures the amount spent on vaccines per surviving child between 0 and 5 years old, using purchasing power parity adjusted values. Ideally, this indicator would compare the amount of money that is spent on vaccines per surviving child (adjusted for local factors) with the amount needed to deliver a standard package of vaccines in different countries, but data regarding this is missing.

An indicator that we would have ideally liked to include to track vaccination financing, but could not due to data limitations is:

- **Timely financing:** In addition to sufficient financing, the level of funding must be stable as to avoid delays in delivery. The delay in delivering the vaccines would allow

[15] Thanks to Orin Levine for suggesting this indicator.

diseases to spread and the untimely immunization could make vaccines ineffective. However, we don't have a way to quantify the timeliness of financing, so we omit this indicator.

Dimension 3. Completeness of Vaccination Data

In this dimension, we capture the completeness of data collection efforts for tracking vaccination performance and financing. In order to do this, we report:

- **How many missing fields every country has for every indicator in the index**
- **Having conducted a household survey which reports vaccination outcomes in the last 5 years (2007-2011) (Measure DHS and IHME)**

By reporting the results of this dimension, we seek to encourage countries to report to vaccination databases by WHO and UNICEF, as well as conduct regular household surveys.

Dimension 4: Fair share of funding to global vaccination efforts

As vaccination is a global public good, we seek to measure how countries with the ability to pay contribute to global vaccination efforts. As discussed in section one, vaccination has two aspects that fall into the sphere of global public goods: research and development, as well as prevention and control of communicable diseases. Given this, countries should contribute their *fair share* to such efforts, and a way to measure this would be to look at how much they contribute to global public goods in health as a percentage of their economic share in the world. Another way to measure this would be to look at how a country provides funding according to the net benefits it receives from the global elimination of vaccine-preventable diseases – a measure of "relative gains" from the elimination of vaccine-preventable diseases.

Given data constraints, we include three indicators in this category, all of which are expressed as a share of country's GDP, and are averaged across the last 5 years to account for historical contributions.

- **Average spending on neglected disease research and development, 2007-2011:** As described in section two, research and development is a global public good which also entails economic and social returns for The most comprehensive database available on contributions to vaccine research and development is G-FINDER, so we compute each country contribution to R&D in 2010 (last available data) with respect to their GDP.
- **Average contributions to GAVI, 2007-2011:** GAVI is the principal global health funder that can be classified as a global public good in terms of vaccination, as it also incorporates the International Finance Facility for Immunization (IFFIm) and

Advance Market Commitments (AMC) for the pneumococcal vaccine. We look into the

- **Average contributions to Global Polio Eradication Initiative (GPEI), 2007-2011:** The World Health Organization's latest global vaccine action plan calls for the eradication of polio and the GPEI is the principal umbrella for these efforts.[16] Given the fact that eradication is the purest global public good, we include contributions to the GPEI in this dimension.

IV. Methodology and Limitations

The Index of Vaccination Commitment (IVC) aims to measure the effort that countries make towards national and global prevention and control, and where possible, elimination of vaccine-preventable diseases. The first two dimensions considered are then combined to quantify vaccination performance and financing.

A fundamental issue is applying weights across dimensions and within sub-dimensions. There may be plausible technical arguments for weighting some dimensions and sub-dimensions more than others. However, constructing reasonable weights would require greater empirical evidence on the connection between each measure and the outcome of interest (VPD or vaccination coverage); for example, ideally, we would like to show that an improvement in financial contributions to global vaccination efforts like GAVI lead unambiguously to a given share of an increase in immunization coverage in recipient countries. However, since empirical evidence on the determinants of better global vaccination performance is missing, we are not able to make a persuasive technical argument to weigh dimensions differently. Further, results of a principal component analysis (see appendix 2) show that the indicators can be averaged together within the first dimension with equal weights. For the second dimension, however, the analysis shows that the variation is better captured with two separate dimensions; yet, for theoretical purposes, we combine all the financing indicators together within a dimension and weight them equally.

As the indicators are often in different units of measurement (some variables are in values, whereas other variables take values from 0 to 100), we standardize each indicator with respect to its maximum value. Thus, the index takes values between 0 and 1.

The IVC for the country *I* and dimension *D* (own vaccination performance, own vaccination financing and fair share to global vaccination efforts & contributions to vaccine research and development) can be formally defined as follows:

$$IVC_i^D = \frac{1}{s}\sum_{s=1}^{s}\frac{V_i^s}{\max\{V_s\}}$$

[16] "Poliomyelitis: intensification of the global eradication initiative" http://apps.who.int/gb/ebwha/pdf_files/WHA65/A65_R5-en.pdf; accessed June 11, 2012

Where *D* is one of 3 dimensions and *S* is each sub-dimension of each dimension, V_i^s is the value of sub-dimension s in the country *i* and $\max\{V_s\}$ is the maximum value of sub-dimension *s*.

The composite index for the country *i* can be defined as follows (and is the average of each dimension):

$$IVC_i{}^D = \frac{1}{D}\sum_{d=1}^{D} CVI_i{}^D$$

Where *D* is one of the 3 considered dimensions.

It is important to recognize the limitations of this index. The first limitation is related to time inconsistency: the index both looks at the average performance over the last three decades, as well as last year's vaccination outcomes, for the first dimension on countries' own vaccination performance. While this is necessary to measure longer-term commitment to vaccination, it rewards current performance more than historical performance. Further, years of performance and financing do not match, as the Joint Reporting Process is not updated every year.

The second limitation is related to inadequate data: as we discussed in the previous section, the issue of data availability limits our effort. Data on household surveys, as well as government resources devoted to vaccination, is hard to find for both developed and developing countries.

In administrative data, both numerators and denominators can be problematic. The numerator –ideally, the number of children vaccinated with a given vaccine- can be measured and reported as the total number of vaccines purchased, distributed or administered, rather than the number of individual children that received a full course of DTP, for example. Paper-based reporting systems that depend on campaign reports, health facility staff and limited supervision by EPI managers may contain inaccuracies. Health facilities reporting to the EPI may not be accessible to some portion of the population, and vaccination occurring in the private sector may be omitted. The denominator - the number of children in the target population- is based on census projections that can be significantly out-of-date and do not take migration within and outside the country into account. As a result, household survey-based vaccination rates are considered more reliable measures of performance, particularly when rates are calculated based on each child's vaccination card (Bos and Batson, 2000).

WHO and UNICEF carry out adjustments to administrative data based on recent survey data, vital statistics and country consultations (Burton et al, 2009). Yet despite these adjustments, there remain significant discrepancies between WHO/UNICEF estimates and Demographic and Household Survey (DHS) data; WHO states that "In no instance do we have complete, consistent, multiple measures for an entire country/vaccine time series"

(Burton et al, 2009). Lim et al (2008) also found systematic over-reporting of vaccination coverage when based on administrative data, up to an overestimation of four times in countries such as Pakistan. However, in the absence of alternative comprehensive sources of data on coverage, this index relies on the JRP.

V. Results

In this section we present the results of our index. We look at individual rankings within each dimension, as each of them measure different aspects, and in the end average the dimensions related to performance and financing.[17]

Dimension 1: Own vaccination performance

Rather unsurprisingly, the top 20 in this dimension are all upper middle income economies from Europe or high income countries. The countries in the bottom 20 are mostly least developed countries. A notable exception among low performers is India, which is ranked 177th out of 193. Other LMIC are also towards the bottom of the ranking, notably Pakistan (169th), Nigeria (183rd) and Indonesia (166th). This shows that many middle-income countries need to work on increasing their vaccination progress and shows the need to question whether cutting health aid to these countries is a feasible and efficient decision (Glassman et al 2011), especially in terms of GAVI Alliance eligibility policies.

Figure 1 shows own vaccination performance around the world. There are several high income countries that have relatively low own vaccination rates such as Australia, Austria, Germany, Greece, Ireland, Japan, Portugal and the United Kingdom. Moreover, the countries that have more periods with more than 85% of coverage between 1980 and 2010 are high income countries, while low income countries are those who have higher rates of increase in coverage.

[17] We report top and bottom 20 in each indicator. Detailed spreadsheets are posted online.

Figure 1. Spatial distribution of own vaccination performance

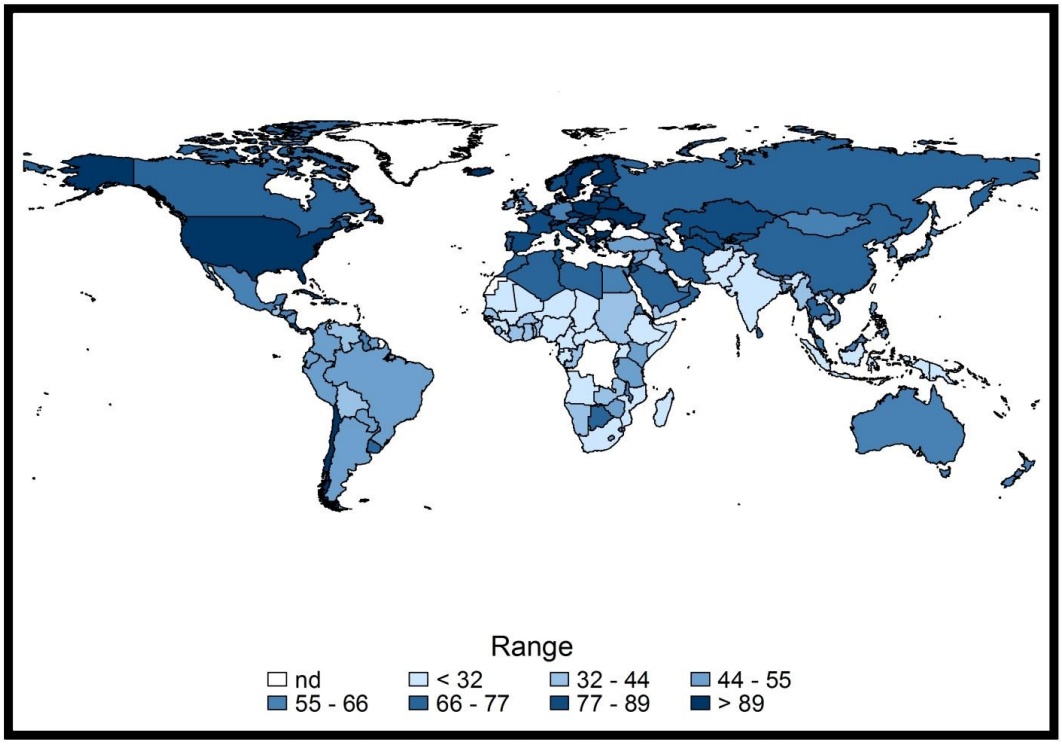


Table 2. Dimension 1, best and worst performers

Country	Income group	DTP-3 Coverage (2010)	Average coverage (1980-2010)	Percentage of periods with more than 85 coverage (1980-2010)	**Average**	**Rank**
Slovakia	High income: OECD	99.0%	99.0%	100.0%	**100.0%**	**1**
Hungary	High income: OECD	99.0%	99.0%	100.0%	**100.0%**	**1**
Monaco	High income: nonOECD	99.0%	98.9%	100.0%	**100.0%**	**3**
Czech Republic	High income: OECD	99.0%	98.0%	100.0%	**99.7%**	**4**
Sweden	High income: OECD	98.0%	98.8%	100.0%	**99.6%**	**5**
Finland	High income: OECD	99.0%	96.9%	100.0%	**99.3%**	**6**
Poland	High income: OECD	99.0%	96.9%	100.0%	**99.3%**	**7**
Andorra	High income: nonOECD	99.0%	95.9%	100.0%	**98.9%**	**8**
Netherlands	High income: OECD	97.0%	96.9%	100.0%	**98.6%**	**9**
Iceland	High income: OECD	96.0%	97.8%	100.0%	**98.6%**	**10**
Romania	Upper middle income	97.0%	96.5%	100.0%	**98.5%**	**11**
Albania	Upper middle income	99.0%	95.9%	96.8%	**97.9%**	**12**
Slovenia	High income: OECD	96.0%	95.3%	100.0%	**97.7%**	**13**
Bulgaria	Upper middle income	94.0%	96.5%	100.0%	**97.5%**	**14**
Brunei Darussalam	High income: nonOECD	95.0%	94.4%	100.0%	**97.1%**	**15**
FYR Macedonia	Upper middle income	95.0%	94.2%	100.0%	**97.0%**	**16**
San Marino	High income: nonOECD	92.0%	96.7%	100.0%	**96.9%**	**17**
Belarus	Upper middle income	98.0%	94.4%	94.7%	**96.3%**	**18**
Switzerland	High income: OECD	96.0%	91.1%	100.0%	**96.3%**	**19**
Dominica	Upper middle income	98.0%	95.3%	93.5%	**96.3%**	**20**
Angola	Lower middle income	91.0%	35.5%	3.6%	**43.8%**	**174**
Madagascar	Low income	74.0%	54.4%	0.0%	**43.2%**	**175**
Mali	Low income	76.0%	48.0%	0.0%	**41.8%**	**176**
India	Lower middle income	72.0%	50.8%	0.0%	**41.4%**	**177**
Liberia	Low income	64.0%	51.3%	0.0%	**38.8%**	**178**
Lao PDR	Low income	74.0%	37.2%	0.0%	**37.4%**	**179**
Mauritania	Low income	64.0%	46.2%	0.0%	**37.1%**	**180**
Papua New Guinea	Lower middle income	56.0%	52.8%	0.0%	**36.6%**	**181**
Uganda	Low income	60.0%	46.1%	0.0%	**35.7%**	**182**
Nigeria	Lower middle income	69.0%	35.6%	0.0%	**35.2%**	**183**
DR Congo	Low income	63.0%	36.7%	0.0%	**33.6%**	**184**
Haiti	Low income	59.0%	40.5%	0.0%	**33.5%**	**185**
Gabon	Upper middle income	45.0%	53.4%	0.0%	**33.1%**	**186**
Niger	Low income	70.0%	28.2%	0.0%	**33.1%**	**187**
Guinea	Low income	57.0%	41.2%	0.0%	**33.1%**	**188**
Afghanistan	Low income	66.0%	30.3%	0.0%	**32.4%**	**189**
Central African Rep	Low income	54.0%	41.5%	0.0%	**32.2%**	**190**

Country	Income group	DTP-3 Coverage (2010)	Average coverage (1980-2010)	Percentage of periods with more than 85 coverage (1980-2010)	**Average**	**Rank**
Chad	Low income	59.0%	24.4%	0.0%	**28.1%**	**191**
Equatorial Guinea	High income: nonOECD	33.0%	45.5%	0.0%	**26.4%**	**192**
Somalia	Low income	45.0%	25.4%	0.0%	**23.7%**	**193**

N	193
Mean	0.74
Median	0.79
Standard Deviation	0.21

Dimension 2: Own vaccination financing

Most developed economies fare well in financing their own vaccination initiatives; however, there are certain cases where countries perform below the average (e.g. France, Germany and Sweden). The ranking shows that although low and lower middle income countries do worse in general, there are several LMIC that do well on funding their own programs (Mali, Malawi, Tajikistan, Tanzania, Ecuador and Morocco). Surprisingly, there is a negative relationship between the income level and the existence of a line item in the national budget for purchase of vaccines and injection supplies (syringes, needles, sharp boxes) used in routine immunizations. Lower income countries are more likely to have a line item in the national budget for immunization, possibly as a result of international advocacy. A study by Lydon et al (2008) shows that countries with a specific line item on their budgets for vaccination spend more on routine immunization financing.

With respect to the level of immunization spending financed using government funds, lower income countries are at the bottom of the ranking where the level is on average lower than 60%, while other income group average levels are above 80% and at the top are the high income groups with almost 95%.

As expected, higher income countries spend more PPP dollars per infant than lower income countries. The difference between country income groups is very pronounced; on average high income countries spend $69, upper-middle income countries spend $25, lower-middle income countries spend $8 and low-income countries spend $1 per infant. An analysis by Saxenian and Hecht (2006) shows that the cost of the Expanded Program on Immunization (EPI), net of HPV and rota, used to be $62 per child; a figure that has now dropped to $38 (Medecins Sans Frontieres, 2012). Both these studies show that low-income countries will not be able to finance their own immunization programs given their current levels of spending.

Figure 2. Spatial distribution of contribution to own vaccination spending

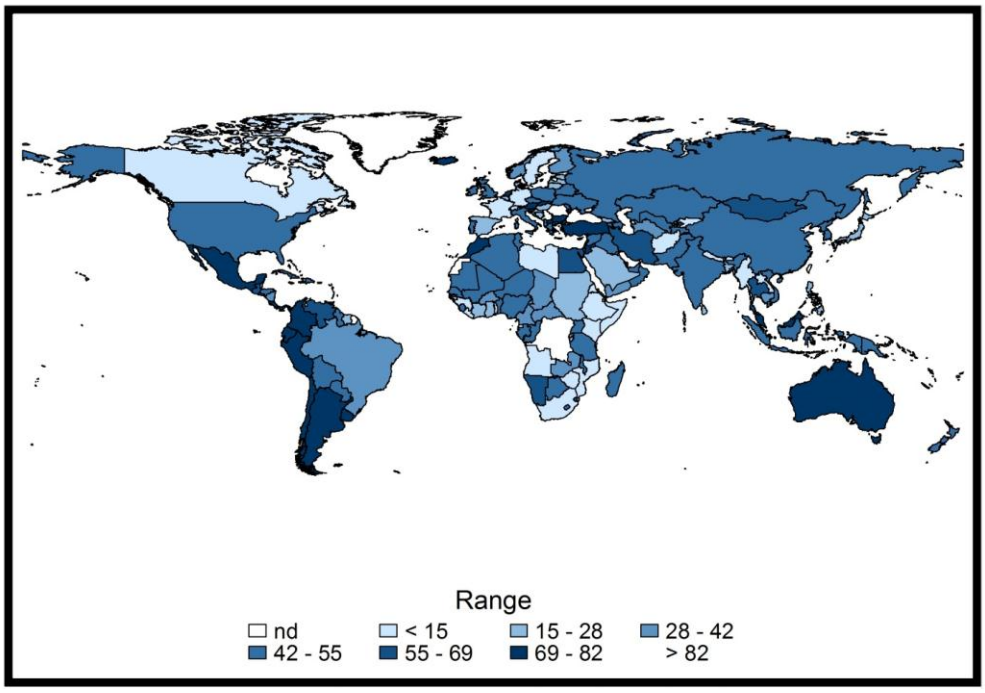
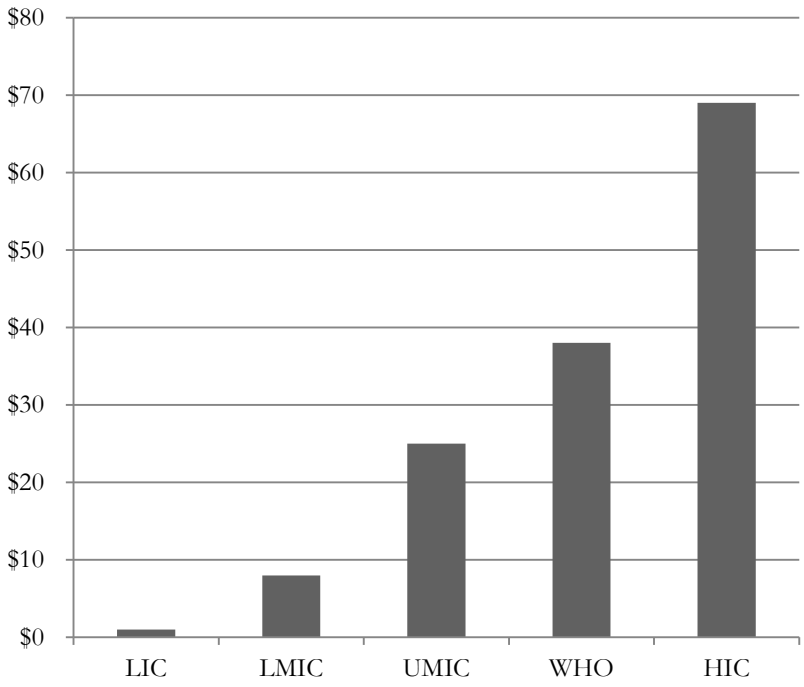


Figure 3. Vaccine spending per infant by income group; cost of a full load of WHO vaccines



Source: Own calculations from WHOSIS; Medecins Sans Frontieres (2012)

Table 3. Own Vaccination Financing: Best and worst performers

Country	Income group	% of immunization spending financed using Government funds (2010)	Line item in the national budget for purchase of vaccines*	Health expenditure as a % of GDP (2010)	Vaccines expenditure as % of Health expenditure	Vaccines expenditure as a % of GDP	Vaccine Spending PPP, ages 0-5	Average	Rank
Qatar	High income: nonOECD	87%	1	2.50%	0.67%	0.02%	271.17	96%	1
Slovakia	High income: OECD	100%	1	8.50%	0.30%	0.03%	99.44	79%	2
Slovenia	High income: OECD	100%	1	9.10%	0.19%	0.02%	89.81	78%	3
Costa Rica	Upper middle income	100%	1	10.50%	25.99%	2.73%	72.42	76%	4
FYR Macedonia	Upper middle income	100%	1	6.90%	0.61%	0.04%	71.60	75%	5
Netherlands	High income: OECD	100%	1	10.80%	0.10%	0.01%	66.47	75%	6
Ecuador	Lower middle income	100%	1	6.10%	0.90%	0.05%	57.91	74%	7
Luxembourg	High income: OECD	100%	0.5	7.80%	0.19%	0.01%	186.09	73%	8
Morocco	Lower middle income	100%	1	5.50%	0.21%	0.01%	50.09	73%	9
Iceland	High income: OECD	100%	1	8.20%	0.10%	0.01%	42.08	72%	10
Chile	Upper middle income	100%	1	8.30%			39.53	72%	11
Panama	Upper middle income	87%	1	8.30%	0.72%	0.06%	74.31	71%	12
Romania	Upper middle income	100%	1	5.40%	0.15%	0.01%	34.80	71%	13
Turkey	Upper middle income	100%	1	6.70%	0.49%	0.03%	32.06	71%	14
Mexico	Upper middle income	100%	1	6.50%	0.33%	0.02%	31.03	70%	15
Uruguay	Upper middle income	100%	1	7.40%	0.21%	0.02%	30.01	70%	16
Austria	High income: OECD	100%	1	11.10%	0.03%	0.00%	25.17	70%	17
Australia	High income: OECD	100%	0.5	8.50%	0.33%	0.03%	159.40	70%	18
Argentina	Upper middle income	100%	1	9.50%			23.04	69%	19
Malaysia	Upper middle income	100%	1	4.80%	0.17%	0.01%	21.23	69%	20
Tuvalu	Lower middle income	2%	1	0.105				34%	174
Micronesia (Federated States of)	Lower middle income	1%	1	0.138			0.453126	34%	175
Togo	Lower middle income	1%	1	0.055	0.002117	0.000116	0.315526	34%	176
Guinea	Lower middle income	0	1	0.057	0.001518	8.65E-05	0.354055	33%	177
Sweden	High income: OECD	100%	0	0.098				33%	178
Switzerland	High income: OECD	100%	0	0.113				33%	179

Country	Income group	% of immunization spending financed using Government funds (2010)	Line item in the national budget for purchase of vaccines*	Health expenditure as a % of GDP (2010)	Vaccines expenditure as % of Health expenditure	Vaccines expenditure as a % of GDP	Vaccine Spending PPP, ages 0-5	Average	Rank
Guinea-Bissau	Low income	0%	1	0.061				33%	180
South Africa	Upper middle income	28%	0.5	0.085	0.003278	0.000279	33.55348	30%	181
France	High income: OECD	90%	0	0.117				30%	182
Somalia	Low income	28%	0.5	0				26%	183
Equatorial Guinea	High income: nonOECD	74%	0	0.039	0.000411	1.6E-05	0.62453	25%	184
Germany	High income: OECD	20%	0.5	0.114				23%	185
Mozambique	Low income	15%	0.5	0.062	0.005711	0.000354	1.228332	22%	186
Bhutan	Lower middle income	63%	0	0.055			0.201074	21%	187
Afghanistan	Low income	11%	0.5	0.074	0.000418	3.09E-05	0.1409	20%	188
Haiti	Low income	10%	0.5	0.061	0	0		20%	189
Djibouti	Lower middle income	26%	0	0.07				9%	190
Eritrea	Low income	20%	0	0.022			0.33787	7%	191
Myanmar	Low income	15%	0	0.02				5%	192
Zimbabwe	Low income	3%	0	0.081				1%	193

N	193
Mean	0.56
Median	0.64
Standard Deviation	0.16

Dimension 3: Completeness of data[18]

In this dimension, we averaged two indicators: whether the country has conducted a household survey in the last five years, and how many indicators the country has as missing from the first two dimensions. We find that 39 countries have filled all indicators and have conducted a household survey and 45 countries have not conducted a household survey and have three out of the seven indicators as missing in the first dimensions.

Dimension 4: Contribution to global vaccination efforts

In this dimension, where we look at G20 countries and high-income countries, we see that Norway, United Kingdom and Ireland contribute most to global vaccination efforts as part of their GDP, whereas Indonesia and Argentina rank last. Countries that stand to benefit the most – such as India and China – also score below average in terms of contributing to global vaccination efforts.

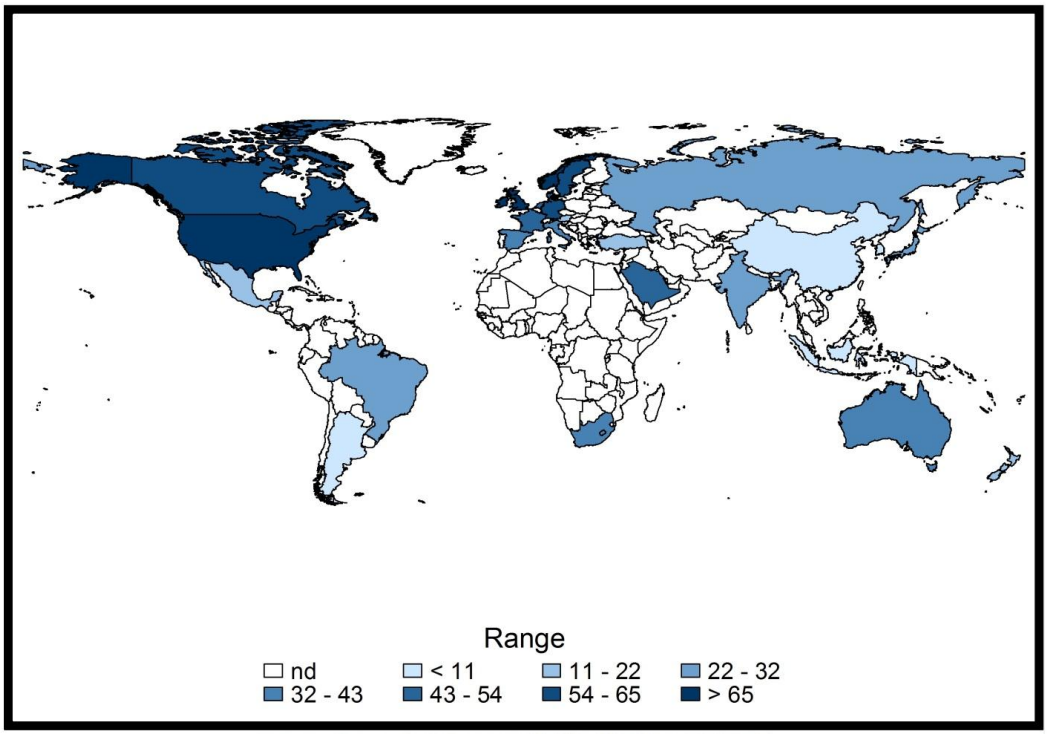
Table 4. Contribution to Global Vaccination Efforts, Results

Country	Average Contributions to R&D; 2007-2012, USD	Average Contributions to GPEI; 2007-2012, USD	Average Contributions to GAVI; 2007-2012, USD	Score	Rank
Norway	15,414,625	92,444,841	8,814,000	75.62%	1
United Kingdom	196,133,800	89,460,379	53,948,000	64.70%	2
Ireland	11,192,580	4,847,277	4,600,000	47.83%	3
United States	1,355,798,390	76,802,600	133,410,000	47.32%	4
Luxembourg	1,662,255	1,142,510	1,284,000	47.28%	5
Canada	17,525,245	56,552,909	24,898,000	33.11%	6
Sweden	24,779,395	38,045,760	0	30.97%	7
Germany	24,223,103	6,338,553	54,946,000	25.53%	8
Saudi Arabia	0	0	8,000,000	25.03%	9
The Netherlands	28,773,177	33,816,101	167,500	19.12%	10
Denmark	12,700,024	6,110,324	0	16.83%	11
France	66,580,944	58,611,202	2,650,000	13.53%	12
Australia	23,071,047	15,106,180	630,000	9.92%	13
Italy	4,841,335	70,523,267	5,368,000	9.30%	14
Spain	19,696,806	20,530,270	2,062,000	8.81%	15
South Africa	6,696,616	966,000	0	7.78%	16
Japan	6,515,461	9,347,826	22,646,000	7.01%	17
Russian Federation	8,180,636	8,000,000	4,200,000	6.70%	18

[18] See online spreadsheet for complete rankings of this dimension.

Country	Average Contributions to R&D; 2007-2012, USD	Average Contributions to GPEI; 2007-2012, USD	Average Contributions to GAVI; 2007-2012, USD	Score	Rank
India	22,115,149	0	300,000	5.94%	19
Brazil	21,277,370	0	0	4.05%	20
New Zealand	0	0	253,333	2.63%	21
Austria	0	0	493,333	1.77%	22
Mexico	2,189,597	0	0	0.74%	23
Turkey	41,515	0	70,000	0.16%	24
China	1,311,948	0	0	0.09%	25
Republic of Korea	6,791	0	0	0.00%	26
Argentina	0	0	0	0.00%	27
Indonesia	0	0	0	0.00%	27

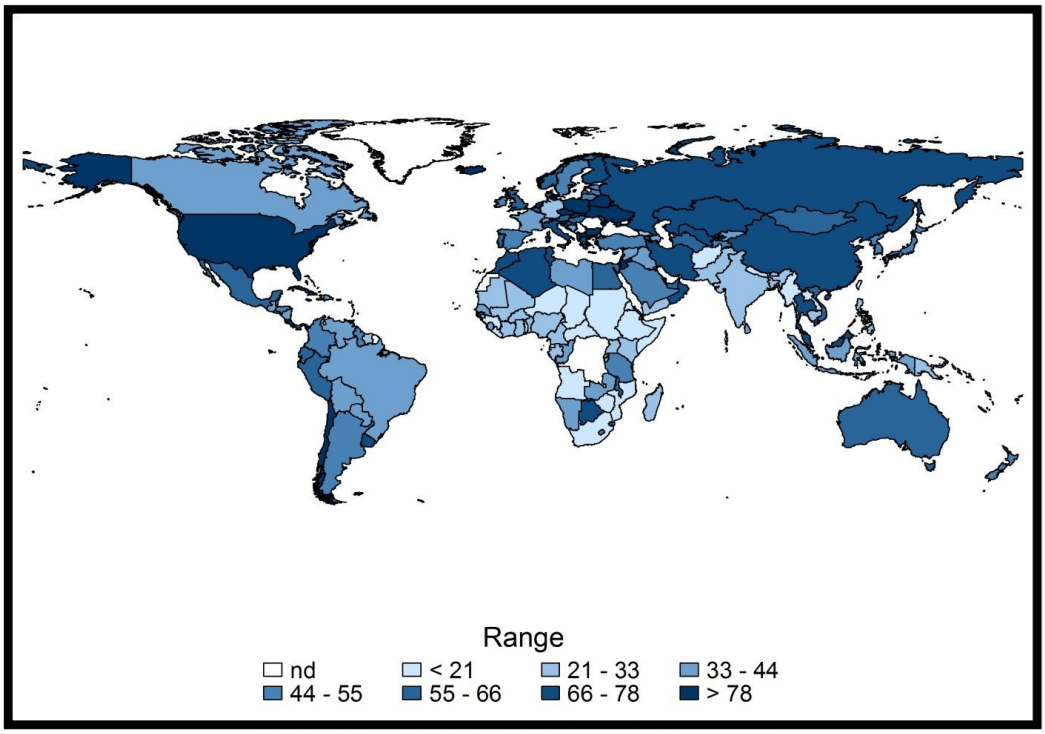
Figure 4. Spatial distribution of contribution to global vaccination efforts



Average of Dimensions 1 and 2

When considering performance and financing dimensions together, we find that most high-income countries are at the top of the index, although several middle income countries also make the top 20, namely Chile, Macedonia, Montenegro, Dominica and Belarus. Not surprisingly, at the bottom of the index, we find most of the low income countries.

Figure 5. Spatial distribution of the composite index (dimensions 1 and 2)



BOX 2. How do populous middle-income countries fare in the index?

In this paper, we frame vaccination as a global public good and track country commitment accordingly. This argument implies that global health donors – or governments – should invest in places where they can leverage more impact, as measured by saving lives. Currently, above 40% of the world's unvaccinated children live in five populous middle-income countries: Pakistan, India, Nigeria, China and Indonesia – or the PINCIs (Glassman et al, 2011), and sustaining vaccine preventable disease elimination, or eradication, will rely on success in these countries.

When we look at the ranking of these five countries in the overall dimension, unsurprisingly, we see a close correlation with per capita incomes: China ranks 46th on the overall index, followed by Indonesia (137th), Pakistan (145th), India (152nd) and Nigeria (169th). Most of these countries fare worse than many GAVI eligible countries, suggesting that a new approach is needed to increase vaccination outcomes in these

countries. What is more important is that all of these countries fare better in own vaccination financing than own vaccination performance, suggesting additional room for external financing.

Table 5. Composite index of Dimensions 1 and 2: best and worst performers

Top 20	Bottom 20
Slovakia	Eritrea
Qatar	Togo
Slovenia	Nepal
Netherlands	Central African Republic
FYR Macedonia	Angola
Iceland	Ethiopia
Romania	Chad
Chile	Guinea-Bissau
Luxembourg	South Africa
Costa Rica	Lao PDR
Bulgaria	Liberia
Andorra	Guinea
Poland	Mozambique
Albania	Zimbabwe
Belarus	Myanmar
Dominica	Djibouti
Montenegro	Haiti
Israel	Afghanistan
United States	Equatorial Guinea
Ukraine	Somalia

VI. Conclusions

In this paper, we define and rank country commitment to vaccination, with the goal of assessing and expanding measures of performance, focusing attention on the determinants of performance, on the role of each country's government in achieving global vaccination-related goals, and on improving the quality and scope of statistical data on vaccination program performance.

We were limited by data availability and quality, and omitted certain indicators. The new indicators suggested here can be considered in future versions of the WHO/UNICEF Joint Reporting Process, while improved adjustments and more frequent independent survey-based measurement may also add to our collective ability to track vaccination program performance accurately.

We find that populous middle-income countries, which stand to gain tremendously from increased vaccination uptake, perform poorly in terms of their vaccination outcomes. In terms of financing, it seems that most middle-income countries end up financing their vaccination outcomes; yet, this is not entirely meaningful by itself given the fact that our index does not calculate the financing gap in vaccination given the lack of available data. The ranking also shows the potential for external aid for populous low- and middle-income countries which fare better in financing than in their outcomes (such as India, Pakistan and Nigeria, which have much higher rankings in this dimension as opposed to the level of their outcomes).

As many donors move into a period of austerity, they are forced to decide between various interventions. Despite the overall flat-lining in health spending, vaccination spending by donors remains significant. Yet, sustained investment is required by countries across the board in order to protect and build on current gains. By ranking countries across performance, own financing and contributions to global public goods, we are hoping to highlight the different dimensions of the issue and make the case sustained investment in vaccination where it is cost-effective.

VII. References

Archibugi, D., & Bizzarri, K. (2004). Committing to vaccine R&D: a global science policy priority. *Research Policy*, *33*(10), 1657-1671. doi:10.1016/j.respol.2004.10.003

Aylward, R. B., Acharya, A., England, S., Agocs, M., & Linkins, J. (2003). Global health goals : lessons from the worldwide effort to eradicate poliomyelitis. *The Lancet*, *362*, 909-914.

Barder O., Kremer M., Levine R., Making Markets for Vaccines: Ideas to action. Working Group Report. Washington DC, Center for Global Development, 2005. Available at: http://www.cgdev.org/section/initiatives/_archive/vaccinedevelopment/chapters. Accessed January 2012.

Bloom, D. E., Canning, D., & Weston, M. (2005). The Value of Vaccination. World Development, 6(3), 15-40.

Bos, E., Batson, A. 2000. "Using Immunization Coverage Rates for Monitoring Health Sector Performance: Measurement and Interpretation Issues" http://siteresources.worldbank.org/HEALTHNUTRITIONANDPOPULATION/Resources/281627-1095698140167/Bos-UsingImmunization-whole.pdf. Last accessed 8/3/2012

Burton et al. WHO and UNICEF estimates of national infant immunization coverage: methods and processes. Bulletin of the World Health Organization. 2009;87:535-541. http://www.who.int/bulletin/volumes/87/7/en/. Last accessed 8/3/2012

Cernuschi, T.; Furrer, E.; McAdams, S.; Jones, Andrew; Fihman, J; Schwalbe, N. "Pneumococcal Advance Market Commitment: Lessons Learnt on Disease and Design Choices and Processes" The GAVI Alliance White Paper.

Dollar, D. (2001). Is globalization good for your health ? *World Health*, *79*(01), 827-833. http://www.who.int/bulletin/archives/79(9)827.pdf

Edejer, T. et al, 2003. WHO Guide to Cost-Effectiveness Analysis. http://www.who.int/choice/publications/p_2003_generalised_cea.pdf. Last accessed 7/31/2012

Fine, P. E. M. (1993). Herd Immunity : History, Theory, Practice. *Epidemiologic Reviews*, *15*(2).

GAVI Alliance, Donor contributions and Proceeds to GAVI (2000-2030), 2011. http://www.gavialliance.org/funding/

G-FINDER , Public Search Tool. 2012. https://g-finder.policycures.org/gfinder_report/

Glassman A., Duran D., and Sumner A. 2011. "Global Health and the New Bottom Billion: What Do Shifts in Global Poverty and the Global Disease Burden Mean for GAVI and the Global Fund?" CGD Working Paper 270. Washington, D.C.: Center for Global Development. http://www.cgdev.org/content/publications/detail/1425581

Global Health Technologies Coalition and Policycures, 2012. "Saving lives and creating impact: why investing in global health research works" http://www.ghtcoalition.org/files/Savinglivesandcreatingimpact.pdf

Global Polio Eradication Initiative, Financing. http://www.polioeradication.org/Portals/0/Document/AnnualReport/AR2010/GPEI_AR2010_EN_A4_WEB_Section_8.pdf Accessed May 20, 2012

IMF World Economic Outlook Database, April 2012. http://www.imf.org/external/pubs/ft/weo/2012/01/weodata/index.aspx

John, T. and Samuel, R. (2000) Herd immunity and herd effect: new insights and definitions. European Journal of Epidemiology, Volume 16 Number 7.

Kaul, I., & Faust, M. (2001). Global public goods and health: taking the agenda forward. *Bulletin of the World Health Organization*, *79*(9), 869-74. Retrieved from http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2566642&tool=pmcentrez&rendertype=abstract

Klepac, P., Laxminarayan, R., & Grenfell, B. T. (2011). Synthesizing epidemiological and economic optima for control of immunizing infections. *PNAS*. doi:10.1073/pnas.1101694108/-/DCSupplemental.www.pnas.org/cgi/doi/10.1073/pnas.1101694108

LaFond, A.K., Kanagat, N., Sequeira, J.S., Steinglass, R.,Fields, R., & Mookherji, S. (2012). Drivers of Routine Immunization System Performance at the District Level: Study Findings from Three Countries, Research Brief No. 3. Arlington, VA: JSI Research & Training Institute, Inc., ARISE Project for the Bill & Melinda Gates Foundation

Lim, Stephen S., Stein, David B., Charrow, Alexandra and Christopher L. J. Murray. "Tracking progress towards universal childhood immunization and the impact of global initiatives: a systematic analysis of three-dose diphtheria, tetanus and pertussis immunization coverage" Lancet. 2008; 372: 2031-46.

Lydon P, Beyai Pl, Chaudhri I, Cakmak N, Satoulou A, Dumolard L. Government financing for health and specific national budget lines: the case of vaccines and immunization. Vaccine. 2008 Dec 2; 26(51):6727-34.

Macro International Inc. MEASURE DHS STATcompiler. http://www.measuredhs.com, 2011.

Mary Moran, Javier Guzman et al. "Neglected Disease Research and Development: Is Innovation Under Threat?" December 2011, G-FINDER.

Medecins Sans Frontieres Access Campaign, 2012. "The Right Shot: Extending the Reach of Affordable and Adapted Vaccines" www.msfaccess.org

Ozawa, S., Stack, M. L., Bishai, D. M., Mirelman, A., Friberg, I. K., Niessen, L., Walker, D. G., et al. (2011). During the "decade of vaccines," the lives of 6.4 million children valued at $231 billion could be saved. *Health affairs (Project Hope)*, *30*(6), 1010-20. doi:10.1377/hlthaff.2011.0381

P. Freeman and M. Miller, August 2001. "Scientific Capacity to Improve Population Health: Knowledge as a Global Public Good" Prepared for the WHO Commission on Health and Macroeconomics, Working Group 2: Global Public Goods. http://www.emro.who.int/cbi/PDF/PopulationHealth.pdf

Public Health Agency of Canada, 2009. http://www.phac-aspc.gc.ca/im/iyc-vve/pgi-gpv/pdf/brochure-eng.pdf. Last accessed 7/31/2012

Saxenian, H. & Hecht, R. (2006) HPV Vaccines: Costs and Financing. http://screening.iarc.fr/doc/StopCxCa_financing_2006.pdf

Schneegans S. Bamako Call to Action urges new approach to health research. UNESCO Science Sector. 2008. [accessed February 24,

2008]. http://portal.unesco.org/en/ev.php-URL_ID=44108&URL_DO=DO_TOPIC&URL_SECTION=201.html.
Shot at Life, 2012. http://shotatlife.org/assets/downloadables/shot-life_allaboutvaccinesapril2012final.pdf. Last accessed 7/31/2012
Smith, Richard D. 2003. "Global public goods and health" Bulletin of the World Health Organization, 81 (7).
Stack, M. L., Ozawa, S., Bishai, D. M., Mirelman, A., Tam, Y., Niessen, L., Walker, D. G., et al. (2011). Estimated Economic Benefits During The "Decade Of Vaccines" Include Treatment Savings, Gains In Labor Productivity. Health Affairs, 30(6), 1021-1028. doi:10.1377/hlthaff.2011.0382
Stansfield S. et al (2002). "Innovative Financing of International Public Goods for Health."
Tenkorang, D. and Conceicao, P. 2003. "Beyond communicable disease control: health in the age of globalization" Chapter 7 in Kaul, I.P., Conceicao, K., Le coulven and R. Mendoza (editors), Providing Global Public Goods: Managing Globalization, Oxford University Press: New York.
Tenkorang, D. and Conceicao, P. 2003. "Beyond communicable disease control: health in the age of globalization" Chapter 7 in Kaul, I.P., Conceicao, K., Le coulven and R. Mendoza (editors), Providing Global Public Goods: Managing Globalization, Oxford University Press: New York.
The World Bank, World Development Indicators, 2011.
UN, 2010. "Goal 4: Reduce Child Mortality" http://www.un.org/millenniumgoals/pdf/MDG_FS_4_EN.pdf
Walter R. Dowdle, Stephen L. Cochi, The principles and feasibility of disease eradication, Vaccine, Volume 29, Supplement 4, 30 December 2011, Pages D70-D73, ISSN 0264-410X, 10.1016/j.vaccine.2011.04.006. (http://www.sciencedirect.com/science/article/pii/S0264410X11005160)
WHO and UNICEF. "Analysis of the Vaccine Financing Indicators" http://www.who.int/immunization_monitoring/routine/immunization_financing_2004.pdf
WHO Commission on Macroeconomics and Health. Working Group 2. Global public goods for health: the report of Working Group 2 of the Commission on Macroeconomics and Health.
WHO Statistical Information System (WHOSIS) http://www.who.int/whosis/en/
WHO, 1999. "Prevention of Cross-Border Transmission of Malaria" http://www.euro.who.int/__data/assets/pdf_file/0011/98786/E67223.pdf
WHO, 1999. "Prevention of Cross-Border Transmission of Malaria" http://www.euro.who.int/__data/assets/pdf_file/0011/98786/E67223.pdf
WHO/UNICEF Joint Reporting Process. http://www.who.int/immunization_monitoring/routine/joint_reporting/en/index.html
Wolfson, L. J., Gasse, F., Lee-martin, S.-pui, Lydon, P., Magan, A., Tibouti, A., Johns, B., et al. (2008). Estimating the costs of achieving the WHO – UNICEF Global Immunization

Vision and Strategy , 2006 – 2015. *Bulletin of the World Health Organization*, *045096*(December 2007), 2006-2015. doi:10.2471/BLT.07.045096

World Health Organization. Vaccine-preventable diseases: monitoring system 2011 global summary, 2012. http://apps.who.int/immunization_monitoring/en/globalsummary/indicatorselect.cfm

World Health Organization, 2005. "Global status of immunization safety: a report based on the WHO/UNICEF Joint Reporting Form, 2003 update" Weekly epidemiological report

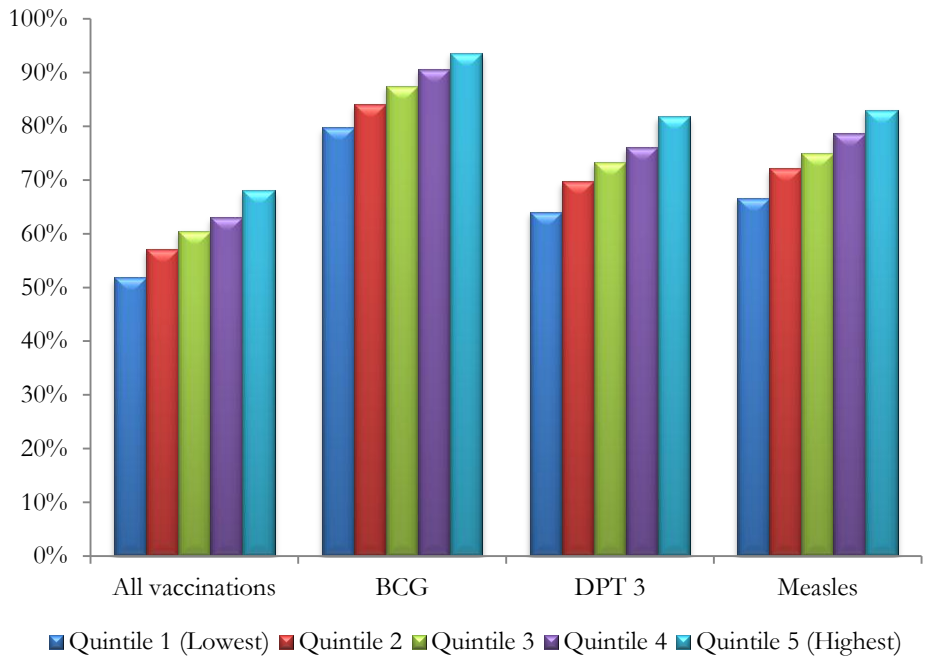
Appendix 1. Inequality in Coverage / Vaccination outcomes by wealth quintiles

When assessing a country's economic performance, it is not enough to only look at the overall GDP per capita, as a high GDP per capita might mask severe inequality and poverty experienced by the bottom quintiles. This is particularly evident in middle-income countries which have experienced a recent and rapid expansion in wealth. Similarly, when looking at vaccination outcomes, it is important to not just look at the overall vaccination rate, as the poorest usually have worse health outcomes. In order to assess this, we look into differences in a country's vaccination outcomes and summarize the inequality in the individual distribution of vaccination coverage. Global indicators like DTP3 coverage average coverage levels reported from administrative sources, but this measure masks very different values for regions or different groups. For example, household surveys in China and India demonstrate that the poorest usually have lower health status and report lower levels of utilization, including lower rates of vaccination.

One data source that can be used to demonstrate the relevance of this topic is the Health Nutrition and Population Statistics by Wealth Quintile database from the World Bank. Building on Demographic and Health Surveys and Multiple Indicator Cluster Surveys, this database has information on vaccination coverage by wealth quintile for several countries[19].We find that the richest quintile has better vaccination outcomes than the poorest quintile across the board: on average, the richest quintile in low-income countries has vaccination rates twice that of the lowest quintile (see the figure on page 12).

[19] Simple unweighted average taken across 87 countries with household surveys that report vaccination outcomes. Please see "HH Survey Data" tab on the spreadsheet for a detailed list.Angola (2001), Armenia (2000), Azerbaijan (2006), Burundi (2005), Benin (2001), Burkina Faso (2006), Bangladesh (2007), Bosnia and Herzegovina (2006), Belarus (2005), Bolivia (2008), Brazil (1996), Central African Republic (2000), Côte d'Ivoire (2006), Cameroon (2006), Congo (2005), Colombia (2005), Comoros (2000), Dominican Republic (2007), Algeria (2006), Egypt (2008), Eritrea (2002), Ethiopia (2005), Gabon (2000), Ghana (2008), Guinea (2005), Gambia (2006), Guinea-Bissau (2006), Guatemala (1999), Honduras (2006), Haiti (2006), Indonesia (2007), India (2006), Jordan (2007), Kazakhstan (2006), Kenya (2009), Kyrgyzstan (1997), Cambodia (2005), Lao People's Democratic Republic (2006), Liberia (2007), Lesotho (2004), Morocco (2004), Republic of Moldova (2000), Madagascar (2009), Maldives (2009), Republic of Macedonia (2005), Mali (2006), Myanmar (2000), Montenegro (2006), Mongolia (2005), Mozambique (2003), Mauritania (2007), Malawi (2006), Namibia (2007), Niger (2006), Nigeria (2008), Nicaragua (2001), Nepal (2006), Pakistan (2007), Peru (2000), Philippines (2008), Paraguay (1990), Rwanda (2008), Sudan (2000), Senegal (2005), Sierra Leone (2008), Somalia (2006), Serbia (2006), Sao Tome and Principe (2000), Suriname (2000), Swaziland (2007), Syrian Arab Republic (2006), Chad (2004), Togo (2006), Thailand (2006), Tajikistan (2005), Turkmenistan (2000), Turkey (1998), United Republic of Tanzania (2005), Uganda (2001), Uzbekistan (2006), Venezuela (2000), Viet Nam (2002), Yemen (2006), South Africa (1998), Congo Democratic Republic (2007), Zambia (2007) & Zimbabwe (2006).

Figure A1. Vaccination performance by economic quintile; average across household surveys[20]



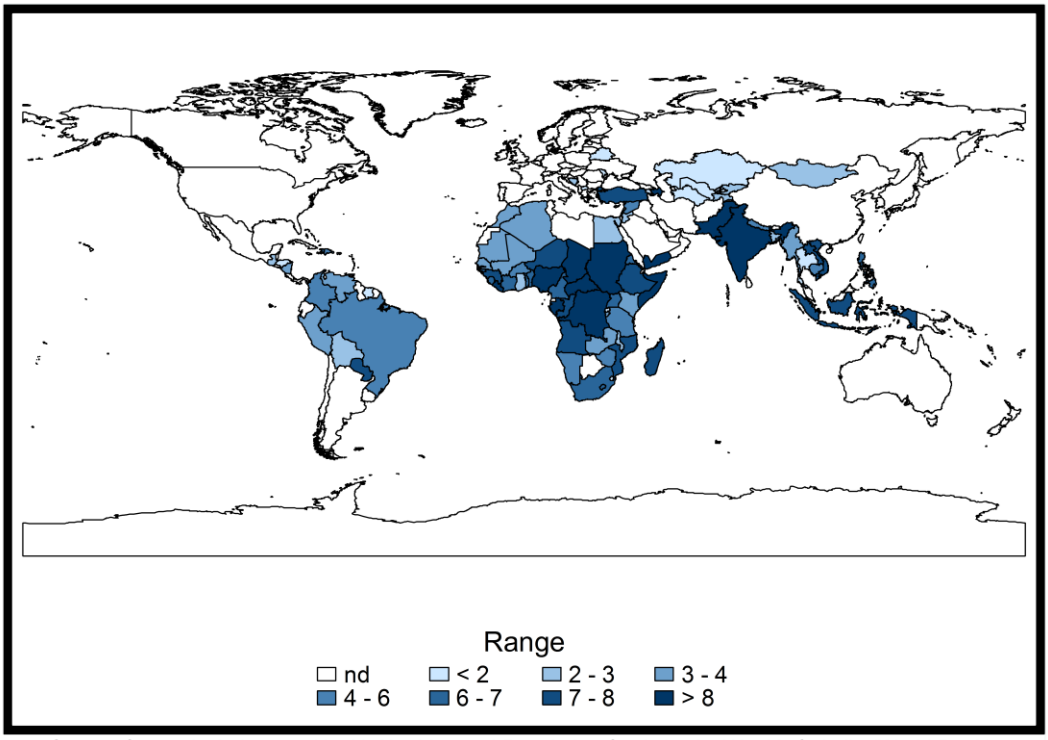
In table 1A we find that the ratio between quintile 5 (wealthiest) and quintile 1 (poorest) in DTP3 vaccination among children ages 12-23 months is on average 1.65 times larger. However, this value varies considering the country income classification; the value is about 1.77 for Low income countries, 1.64 for lower middle and from 1.37 for Upper middle. The extreme values are 9.27 in Nigeria and 9 in Chad. Although the median ratio is not very large, it is notable that among bottom quintile households, the number of children is greater. Therefore, the impact of the difference is relevant in order to design health policies. Another interesting finding is that in several countries the coverage is higher in lower income quintiles than upper income quintiles, as is the case in Armenia, Honduras, Republic of Moldova, Turkmenistan and Suriname.

Table A1. DPT 3 Vaccine ratio between quintile 5 and quintile 1

Income Group	Average	Median	Standard deviation	Variation coefficient	Max
Low income	1.79	1.30	1.49	0.83	9.00
Lower middle	1.64	1.20	1.48	0.91	9.27
Upper middle	1.37	1.23	0.59	0.43	2.99
Total	1.65	1.27	1.35	0.82	9.27

Source: Own calculation on Health Nutrition and Population Statistics by Wealth Quintile database

Figure A2. Spatial distribution of the DTP 3 Vaccine ratio between quintile 5 and quintile 1 (darker color indicates higher vaccination coverage inequality)



Source:Own calculations on Health Nutrition and Population Statistics by Wealth Quintile (World Bank).

The database also allows for analysis of the difference between quintiles for other vaccines (all vaccinations, BCG and Measles) as is shown in table 2B. In that table, when considering all vaccines (complete vaccination), the ratio of inequality reaches a value of 21.45. In the case of BCG and Measles, the difference between quintiles is less marked and has extreme values around 4.5 times. This finding suggests that the poor are less likely to be vaccinated in a complete and timely manner.

TableA2. Vaccine ratio between quintile 5 and quintile 1

Vaccine	Average	Median	Standard deviation	Variation coefficient	Max
DPT 3	1.65	1.35	0.82	9.27	87
All vaccinations	1.94	2.49	1.29	21.45	87
BCG	1.30	0.64	0.49	4.91	86
Measles	1.41	0.65	0.46	4.65	87

Table A3. Data on DTP3 Vaccine coverage, children aged 12-23 months

Country	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
Algeria	88.7	94.5	96.7	97.3	98.2
Angola	23.1	23.4	34.4	36.4	47.3
Armenia	89.3	93.0	86.9	95.5	83.5
Azerbaijan	21.3	23.8	22.0	29.5	63.7
Bangladesh	92.4	86.5	89.9	92.2	94.7
Belarus	100.0	98.3	99.2	98.8	98.0
Benin	63.0	65.1	71.9	76.9	88.8
Bolivia (	85.4	84.4	86.9	85.9	86.1
Bosnia and Herzegovina	79.3	86.2	88.5	88.9	86.2
Brazil	65.6	83.9	90.4	91.3	81.9
Burkina Faso	72.5	70.6	79.2	79.4	92.7
Burundi	57.7	63.2	60.0	69.5	63.8
Cambodia	65.6	78.8	81.0	88.9	84.0
Cameroon	64.5	76.3	73.0	81.6	85.2
Central African Republic	15.6	22.6	24.3	44.1	64.2
Chad	4.7	14.2	17.3	22.4	42.3
Colombia	71.5	79.5	88.3	84.1	88.2
Comoros	59.2	61.9	71.4	72.4	80.3
Congo	42.0	62.4	75.0	80.9	90.7
Congo Democratic Republic	27.8	35.5	43.9	52.8	73.2
Côte d'Ivoire	62.0	73.7	82.4	88.8	96.0
Dominican Republic	66.7	75.0	74.6	75.5	85.2
Egypt	96.6	96.2	97.8	98.6	98.9
Eritrea	74.5	74.9	76.9	91.8	96.8
Ethiopia	25.6	26.8	33.0	30.6	47.9
Gabon	17.8	31.6	44.0	41.5	49.1
Gambia	89.2	85.3	84.1	85.8	90.5
Ghana	88.0	86.5	82.1	95.8	93.3
Guatemala	74.3	72.9	79.9	63.9	75.8
Guinea	38.2	45.3	55.8	62.7	61.0
Guinea-Bissau	54.5	60.0	60.6	64.6	76.0
Haiti	45.4	48.4	54.8	50.7	71.8
Honduras	94.3	92.5	93.2	94.1	88.0
India	33.9	47.1	58.4	68.5	81.9
Indonesia	44.9	62.6	66.7	78.2	81.4
Jordan	96.5	97.3	97.8	98.1	98.0
Kazakhstan	98.6	97.6	97.2	98.2	98.4
Kenya	77.3	86.7	91.2	88.8	89.6

Country	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
Kyrgyzstan	82.3	81.8	80.6	79.5	86.9
Lao People's Democratic Republic	29.4	34.0	53.2	46.8	59.0
Liberia	29.6	38.2	55.2	65.7	71.9
Lesotho	80.0	80.0	83.1	81.6	90.0
Madagascar	53.1	67.6	77.1	85.8	92.3
Malawi	83.6	84.8	85.8	88.1	91.2
Maldives	97.7	99.3	96.9	98.1	97.3
Mali	65.1	61.8	67.9	66.6	77.4
Mauritania	53	59	58	52	60
Mongolia	92.1	92.5	90.6	95	96.2
Montenegro	75	95.6	95.7	97.2	96.7
Morocco	89	94.6	96.7	96.9	98.2
Mozambique	52.4	63.8	72.1	86.2	95.6
Myanmar	78.2	81.8	84.6	85.2	88.1
Namibia	74	83.6	78.6	90.2	93.8
Nepal	75.2	88	96	93.4	96.3
Nicaragua	71.9	89.1	87.5	85.5	87.9
Niger	30.5	35.9	30.1	38.9	62.6
Nigeria	8.2	20.8	32.9	52.5	76
Pakistan	34.8	47.6	62.9	72.5	78
Paraguay	39.8	48.8	56.1	60.9	68.7
Peru	76.2	83.9	87.5	90.4	93
Philippines	71.3	86.7	88.5	93.4	94
Republic of Moldova	97.2	98	94.4	91.1	88.7
Rwanda	90.7	88.7	90.9	89.7	89.3
Sao Tome and Principe	63.6	78.1	71.6	79.9	80.7
Senegal	72.4	74.5	81.6	80.1	84.5
Serbia	93.2	96.8	99.8	93	94.5
Sierra Leone	55	58.6	62.2	57.8	72
Somalia	5.4	6.5	14.6	14.7	28.8
South Africa	63.9	76	79	84	84.8
Sudan	26.1	33.6	40.9	53.9	65.3
Suriname	91.3	86.4	84	74.7	71.5
Swaziland	91.7	89.5	93.8	94.4	88.8
Syrian Arab Republic	63.7	77.7	81.8	79.1	81.7
Tajikistan	82	82.3	88.6	91	88.2
Thailand	93.9	95.8	92	94.7	90.8
Republic of Macedonia	85.2	93.8	88.5	85.3	85.5
Togo	58.2	56.2	61.7	72.9	76.3

Country	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
Turkey	45.2	48	62.7	64.4	81.4
Turkmenistan	97.1	98.1	92.4	86.6	85.6
Uganda	34.9	45.2	51.4	47.7	55.1
United Republic of Tanzania	75.2	82.7	88.1	93.4	95.6
Uzbekistan	93.7	95.3	93.3	91.2	92.5
Venezuela	51.4	71.7	60.8	45.3	61.1
Viet Nam	52.8	65.6	78.4	81.4	93.5
Yemen	40.3	50	60.5	65.5	94.6
Zambia	77.4	73	76.3	85.6	93.7
Zimbabwe	56.3	58	61.5	67.5	69.1

Appendix 2. Principal Components Analysis for Dimensions 1 and 2

Dimension 1. Own Vaccination Performance

Principal components/correlation				
Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	2.53727	2.1635	0.8458	0.8458
Comp2	0.373776	0.284826	0.1246	0.9704
Comp3	0.0889498		0.0296	1
	N	193		
	# of components	1		
	Trace	3		
	Rho	0.8458		

Principal components (eigenvectors)		
Variable	Component 1	Unexplained
DTP-3 Coverage (2010)	0.5384	0.2646
Average coverage (1980-2010)	0.5991	0.08945
Percentage of periods with more than 85 coverage (1980-2010)	0.5927	0.1086

Dimension 2. Own Vaccination Financing

Principal components/correlation				
Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	1.13159	0.131546	0.3772	0.3772
Comp2	1.00004	0.13167	0.3333	0.7105
Comp3	0.868371		0.2895	1
	N	193		
	# of components	2		
	Trace	3		
	Rho	0.7105		

Principal components (eigenvectors)			
Variable	Component 1	Component 2	Unexplained
Percentage of immunization spending financed using government funds (2010)	0.7072	0.0001	0.4341
Line item in the national budget for purchase of vaccines and injection supliers	0.4188	0.8056	0.1525
PPP vaccine spending (over pop 0-5)	0.5696	-0.5924	0.2818

Appendix 3. Rate of increase by country; top 10 and bottom 10[21]

Country	Rate of change; 1980-2010
Uruguay	418%
Central African Republic	373%
Sierra Leone	317%
Bangladesh	307%
Saint Lucia	303%
Zimbabwe	303%
Kyrgyzstan	300%
Dominica	297%
Fiji	295%
Saint Kitts and Nevis	284%
…	…
Burundi	-8%
Democratic Republic of the Congo	-13%
Iraq	-14%
Chad	-20%
Senegal	-28%
Palau	-29%
China	-32%
San Marino	-42%
Gabon	-48%
Azerbaijan	-51%

[21] Complete ranking can be found on the online spreadsheet

Appendix 4. Regional rankings within Dimensions 1 and 2

All rankings reported are cumulative rankings within that dimension.

Dimension 1: Own Vaccination Performance

East Asia & Pacific

Country	Income group	Average	Rank
Singapore	High income: nonOECD	92%	47
Tonga	Lower middle income	90%	59
Fiji	Upper middle income	89%	62
Niue		86%	68
Cook Islands		85%	74
China	Lower middle income	85%	75
Thailand	Lower middle income	84%	79
Viet Nam	Lower middle income	83%	82
Malaysia	Upper middle income	83%	85
Japan	High income: OECD	83%	87
Australia	High income: OECD	81%	92
Samoa	Lower middle income	80%	95
Mongolia	Lower middle income	79%	97
Republic of Korea	High income: OECD	79%	98
New Zealand	High income: OECD	76%	107
Tuvalu	Lower middle income	76%	109
Palau	Upper middle income	73%	113
Micronesia (Federated States of)	Lower middle income	70%	120
Marshall Islands	Lower middle income	69%	122
Democratic People's Republic of Korea	Low income	68%	123
Kiribati	Lower middle income	66%	128
Philippines	Lower middle income	66%	132
Nauru		64%	135
Myanmar	Low income	59%	142
Cambodia	Low income	54%	150
Solomon Islands	Low income	51%	156
Indonesia	Lower middle income	48%	166
Timor-Leste	Lower middle income	46%	168
Vanuatu	Lower middle income	45%	170
Lao People's Democratic Republic	Low income	37%	179
Papua New Guinea	Lower middle income	37%	181

Europe & Central Asia

Country	Income group	Average	Rank
Slovakia	High income: OECD	100%	1
Hungary	High income: OECD	100%	1
Monaco	High income: nonOECD	100%	3
Czech Republic	High income: OECD	100%	4
Sweden	High income: OECD	100%	5
Finland	High income: OECD	99%	6
Poland	High income: OECD	99%	7
Andorra	High income: nonOECD	99%	8
Netherlands	High income: OECD	99%	9
Iceland	High income: OECD	99%	10
Romania	Upper middle income	98%	11
Albania	Upper middle income	98%	12
Slovenia	High income: OECD	98%	13
Bulgaria	Upper middle income	97%	14
FYR Macedonia	Upper middle income	97%	16
San Marino	High income: nonOECD	97%	17
Belarus	Upper middle income	96%	18
Switzerland	High income: OECD	96%	19
Belgium	High income: OECD	96%	21
Montenegro	Upper middle income	96%	22
Ukraine	Lower middle income	96%	25
Croatia	High income: nonOECD	95%	29
France	High income: OECD	95%	31
Luxembourg	High income: OECD	95%	33
Uzbekistan	Lower middle income	94%	34
Armenia	Lower middle income	93%	37
Latvia	High income: nonOECD	93%	38
Spain	High income: OECD	93%	39
Denmark	High income: OECD	93%	41
Serbia	Upper middle income	93%	42
Turkmenistan	Lower middle income	92%	44
Kyrgyzstan	Low income	92%	45
Republic of Moldova	Lower middle income	91%	48
Italy	High income: OECD	91%	49
Kazakhstan	Upper middle income	91%	52
Lithuania	Upper middle income	91%	53
Norway	High income: OECD	91%	54
Russian Federation	Upper middle income	90%	57
Estonia	High income: OECD	90%	58
Cyprus	High income: nonOECD	89%	64

Country	Income group	Average	Rank
Portugal	High income: OECD	87%	66
Greece	High income: OECD	85%	77
Germany	High income: OECD	83%	83
United Kingdom	High income: OECD	81%	91
Austria	High income: OECD	79%	99
Bosnia and Herzegovina	Upper middle income	77%	105
Malta	High income: nonOECD	74%	111
Tajikistan	Low income	73%	115
Turkey	Upper middle income	71%	119
Georgia	Lower middle income	68%	125
Ireland	High income: OECD	66%	131
Azerbaijan	Upper middle income	49%	162

Latin America & Caribbean

Country	Income group	Average	Rank
Dominica	Upper middle income	96%	20
Chile	Upper middle income	96%	26
Antigua and Barbuda	Upper middle income	95%	28
Saint Kitts and Nevis	Upper middle income	95%	30
Cuba	Upper middle income	94%	36
Saint Vincent and the Grenadines	Upper middle income	93%	40
Costa Rica	Upper middle income	92%	46
Bahamas	High income: nonOECD	89%	63
Saint Lucia	Upper middle income	86%	71
Uruguay	Upper middle income	86%	72
Jamaica	Upper middle income	84%	80
Honduras	Lower middle income	83%	84
Grenada	Upper middle income	82%	88
Belize	Lower middle income	80%	94
Mexico	Upper middle income	79%	96
Panama	Upper middle income	78%	102
Trinidad and Tobago	High income: nonOECD	77%	103
Barbados	High income: nonOECD	77%	106
Guyana	Lower middle income	76%	108
Peru	Upper middle income	75%	110
El Salvador	Lower middle income	74%	112
Brazil	Upper middle income	73%	114
Argentina	Upper middle income	73%	116
Ecuador	Lower middle income	73%	117

Country	Income group	Average	Rank
Colombia	Upper middle income	67%	127
Paraguay	Lower middle income	66%	129
Nicaragua	Lower middle income	66%	130
Suriname	Upper middle income	64%	137
Guatemala	Lower middle income	62%	141
Dominican Republic	Upper middle income	58%	145
Venezuela (Bolivarian Republic of)	Upper middle income	50%	160
Bolivia (Plurinational State of)	Lower middle income	49%	163
Haiti	Low income	33%	185

Middle East and North Africa

Country	Income group	Average	Rank
Brunei Darussalam	High income: nonOECD	97%	15
Israel	High income: OECD	96%	23
Bahrain	High income: nonOECD	94%	35
Kuwait	High income: nonOECD	92%	43
Jordan	Lower middle income	91%	50
Tunisia	Lower middle income	91%	51
Saudi Arabia	High income: nonOECD	90%	60
Algeria	Upper middle income	89%	61
Oman	High income: nonOECD	88%	65
Libyan Arab Jamahiriya	Upper middle income	86%	73
Iran (Islamic Republic of)	Upper middle income	85%	76
Morocco	Lower middle income	84%	78
Egypt	Lower middle income	82%	89
United Arab Emirates	High income: nonOECD	82%	90
Qatar	High income: nonOECD	81%	93
Syrian Arab Republic	Lower middle income	63%	138
Lebanon	Upper middle income	57%	147
Yemen	Lower middle income	53%	152
Djibouti	Lower middle income	52%	154
Iraq	Lower middle income	50%	159

North America

Country	Income group	Average	Rank	Region
United States	High income: OECD	96%	24	North America
Canada	High income: OECD	86%	69	North America

South Asia

Country	Income group	Average	Rank	Region
Sri Lanka	Lower middle income	86%	70	South Asia
Maldives	Lower middle income	83%	86	South Asia
Bhutan	Lower middle income	77%	104	South Asia
Bangladesh	Low income	63%	139	South Asia
Nepal	Low income	51%	155	South Asia
Pakistan	Lower middle income	48%	165	South Asia
India	Lower middle income	41%	177	South Asia
Afghanistan	Low income	32%	189	South Asia

Sub-Saharan Africa

Country	Income group	Average	Rank
Seychelles	Upper middle income	96%	27
Mauritius	Upper middle income	95%	32
Cape Verde	Lower middle income	90%	55
Botswana	Upper middle income	90%	56
Gambia	Low income	87%	67
Eritrea	Low income	83%	81
Swaziland	Lower middle income	78%	100
Malawi	Low income	78%	101
Sao Tome and Principe	Lower middle income	72%	118
Rwanda	Low income	70%	121
Lesotho	Lower middle income	68%	124
United Republic of Tanzania	Low income	68%	126
Zimbabwe	Low income	64%	133
Burundi	Low income	64%	134
Kenya	Low income	64%	136
Zambia	Low income	62%	140
Ghana	Low income	59%	143
Namibia	Upper middle income	59%	144
Sierra Leone	Low income	57%	146
Burkina Faso	Low income	56%	148

Country	Income group	Average	Rank
Togo	Low income	56%	149
Congo	Lower middle income	53%	151
Senegal	Lower middle income	53%	153
Comoros	Low income	50%	157
Benin	Low income	50%	158
Sudan	Lower middle income	49%	161
Côte d'Ivoire	Lower middle income	49%	164
Cameroon	Lower middle income	46%	167
South Africa	Upper middle income	45%	169
Ethiopia	Low income	45%	171
Mozambique	Low income	45%	172
Guinea-Bissau	Low income	45%	173
Angola	Lower middle income	44%	174
Madagascar	Low income	43%	175
Mali	Low income	42%	176
Liberia	Low income	39%	178
Mauritania	Low income	37%	180
Uganda	Low income	36%	182
Nigeria	Lower middle income	35%	183
Democratic Republic of the Congo	Low income	34%	184
Gabon	Upper middle income	33%	186
Niger	Low income	33%	187
Guinea	Low income	33%	188
Central African Republic	Low income	32%	190
Chad	Low income	28%	191
Equatorial Guinea	High income: nonOECD	26%	192
Somalia	Low income	24%	193

Dimension 2: Own Vaccination Financing

East Asia & Pacific

Country	Income group	Average	Rank
Australia	High income: OECD	70%	18
Malaysia	Upper middle income	69%	20
Mongolia	Lower middle income	68%	32
Thailand	Lower middle income	68%	35
Fiji	Upper middle income	68%	36
Singapore	High income: nonOECD	68%	38
China	Lower middle income	67%	43
Tonga	Lower middle income	67%	45
Indonesia	Lower middle income	67%	50
Viet Nam	Lower middle income	67%	53
Timor-Leste	Lower middle income	67%	61
Cook Islands		67%	67
Democratic People's Republic of Korea	Low income	67%	67
Marshall Islands	Lower middle income	67%	67
Nauru		67%	67
Republic of Korea	High income: OECD	64%	96
Papua New Guinea	Lower middle income	62%	101
Niue		62%	104
New Zealand	High income: OECD	61%	108
Cambodia	Low income	56%	116
Vanuatu	Lower middle income	50%	129
Japan	High income: OECD	50%	132
Kiribati	Lower middle income	50%	132
Philippines	Lower middle income	47%	144
Palau	Upper middle income	46%	145
Solomon Islands	Low income	44%	146
Samoa	Lower middle income	43%	151
Lao People's Democratic Republic	Low income	36%	172
Tuvalu	Lower middle income	34%	174
Micronesia (Federated States of)	Lower middle income	34%	175
Myanmar	Low income	5%	192

Europe & Central Asia

Country	Income group	Average	Rank
Slovakia	High income: OECD	79%	2
Slovenia	High income: OECD	78%	3
FYR Macedonia	Upper middle income	75%	5
Netherlands	High income: OECD	75%	6
Luxembourg	High income: OECD	73%	8
Iceland	High income: OECD	72%	10
Romania	Upper middle income	71%	13
Turkey	Upper middle income	71%	14
Austria	High income: OECD	70%	17
Bulgaria	Upper middle income	69%	24
Cyprus	High income: nonOECD	67%	51
Tajikistan	Low income	67%	54
Kazakhstan	Upper middle income	67%	64
Belarus	Upper middle income	67%	65
Andorra	High income: nonOECD	67%	67
Greece	High income: OECD	67%	67
Ireland	High income: OECD	67%	67
Italy	High income: OECD	67%	67
Montenegro	Upper middle income	67%	67
Russian Federation	Upper middle income	67%	67
Serbia	Upper middle income	67%	67
Ukraine	Lower middle income	67%	67
United Kingdom	High income: OECD	67%	67
Azerbaijan	Upper middle income	67%	91
Albania	Upper middle income	66%	93
Poland	High income: OECD	65%	95
Republic of Moldova	Lower middle income	63%	99
Portugal	High income: OECD	62%	104
Armenia	Lower middle income	62%	106
Czech Republic	High income: OECD	60%	110
Uzbekistan	Lower middle income	59%	111
Norway	High income: OECD	56%	115
Finland	High income: OECD	54%	122
Turkmenistan	Lower middle income	52%	124
Estonia	High income: OECD	50%	128
Belgium	High income: OECD	50%	132
Croatia	High income: nonOECD	50%	132
Denmark	High income: OECD	50%	132

Country	Income group	Average	Rank
Hungary	High income: OECD	50%	132
Malta	High income: nonOECD	50%	132
Monaco	High income: nonOECD	50%	132
Latvia	High income: nonOECD	49%	141
Bosnia and Herzegovina	Upper middle income	48%	142
Spain	High income: OECD	43%	149
Georgia	Lower middle income	42%	155
Lithuania	Upper middle income	42%	156
San Marino	High income: nonOECD	42%	158
Kyrgyzstan	Low income	39%	165
Sweden	High income: OECD	33%	178
Switzerland	High income: OECD	33%	178
France	High income: OECD	30%	182
Germany	High income: OECD	23%	185

Latin America & Caribbean

Country	Income group	Average	Rank
Costa Rica	Upper middle income	76%	4
Ecuador	Lower middle income	74%	7
Chile	Upper middle income	72%	11
Panama	Upper middle income	71%	12
Mexico	Upper middle income	70%	15
Uruguay	Upper middle income	70%	16
Argentina	Upper middle income	69%	19
Trinidad and Tobago	High income: nonOECD	69%	22
Peru	Upper middle income	69%	23
Colombia	Upper middle income	69%	25
Bahamas	High income: nonOECD	69%	26
El Salvador	Lower middle income	68%	27
Grenada	Upper middle income	68%	29
Guatemala	Lower middle income	68%	34
Venezuela (Bolivarian Republic of)	Upper middle income	68%	37
Jamaica	Upper middle income	67%	44
Dominican Republic	Upper middle income	67%	46
Antigua and Barbuda	Upper middle income	67%	67
Barbados	High income: nonOECD	67%	67

Country	Income group	Average	Rank
Cuba	Upper middle income	67%	67
Dominica	Upper middle income	67%	67
Bolivia (Plurinational State of)	Lower middle income	65%	94
Paraguay	Lower middle income	64%	97
Guyana	Lower middle income	63%	98
Honduras	Lower middle income	60%	109
Nicaragua	Lower middle income	57%	112
Brazil	Upper middle income	54%	123
Belize	Lower middle income	52%	125
Suriname	Upper middle income	43%	149
Saint Lucia	Upper middle income	42%	152
Saint Vincent and the Grenadines	Upper middle income	42%	153
Saint Kitts and Nevis	Upper middle income	42%	158
Haiti	Low income	20%	189

Middle East & North Africa

Country	Income group	Average	Rank
Qatar	High income: nonOECD	96%	1
Morocco	Lower middle income	73%	9
Jordan	Lower middle income	69%	21
Egypt	Lower middle income	68%	28
Iran (Islamic Republic of)	Upper middle income	68%	30
Lebanon	Upper middle income	68%	31
Algeria	Upper middle income	67%	40
Oman	High income: nonOECD	67%	41
Tunisia	Lower middle income	67%	42
Syrian Arab Republic	Lower middle income	67%	55
Iraq	Lower middle income	67%	66
Bahrain	High income: nonOECD	67%	67
Israel	High income: OECD	67%	67
United Arab Emirates	High income: nonOECD	67%	67
Kuwait	High income: nonOECD	55%	119
Yemen	Lower middle income	55%	121
Saudi Arabia	High income: nonOECD	42%	158
Brunei Darussalam	High income: nonOECD	40%	164
Libyan Arab Jamahiriya	Upper middle income	38%	168
Djibouti	Lower middle income	9%	190

North America

Country	Income group	Average	Rank
United States	High income: OECD	67%	67
Canada	High income: OECD	39%	166

South Asia

Country	Income group	Average	Rank
India	Lower middle income	67%	59
Maldives	Lower middle income	67%	67
Pakistan	Lower middle income	63%	100
Bangladesh	Low income	47%	143
Sri Lanka	Lower middle income	43%	147
Nepal	Low income	38%	167
Bhutan	Lower middle income	21%	187
Afghanistan	Low income	20%	188

Sub-Saharan Africa

Country	Income group	Average	Rank
Swaziland	Lower middle income	68%	33
Namibia	Upper middle income	68%	39
Mali	Low income	67%	47
Botswana	Upper middle income	67%	48
Malawi	Low income	67%	49
Senegal	Lower middle income	67%	52
United Republic of Tanzania	Low income	67%	56
Mauritania	Low income	67%	57
Congo	Lower middle income	67%	58
Uganda	Low income	67%	60
Madagascar	Low income	67%	62
Sierra Leone	Low income	67%	63
Democratic Republic of the Congo	Low income	67%	67
Lesotho	Lower middle income	67%	67
Gabon	Upper middle income	66%	92
Nigeria	Lower middle income	62%	102
Niger	Low income	62%	103
Benin	Low income	61%	107
Burkina Faso	Low income	57%	113
Cape Verde	Lower middle income	56%	114

Country	Income group	Average	Rank
Cameroon	Lower middle income	56%	117
Central African Republic	Low income	55%	118
Zambia	Low income	55%	120
Chad	Low income	51%	126
Mauritius	Upper middle income	51%	127
Côte d'Ivoire	Lower middle income	50%	130
Comoros	Low income	50%	131
Seychelles	Upper middle income	50%	132
Sudan	Lower middle income	43%	148
Rwanda	Low income	42%	154
Sao Tome and Principe	Lower middle income	42%	157
Gambia	Low income	40%	161
Ghana	Low income	40%	162
Burundi	Low income	40%	163
Angola	Lower middle income	38%	169
Ethiopia	Low income	37%	170
Kenya	Low income	37%	171
Liberia	Low income	34%	173
Togo	Low income	34%	176
Guinea	Low income	33%	177
Guinea-Bissau	Low income	33%	178
South Africa	Upper middle income	30%	181
Somalia	Low income	26%	183
Equatorial Guinea	High income: nonOECD	25%	184
Mozambique	Low income	22%	186
Eritrea	Low income	7%	191
Zimbabwe	Low income	1%	193