CHAPTER 73

Value of Vaccination in India: Past, Present, and Future Prospects

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ABSTRACT

In recent decades, India has made tremendous progress with respect to vaccinating its citizens and promoting the health of its population. Since 2000, India has introduced a number of new vaccines into its universal immunization program and closed or narrowed vaccination coverage gaps with relevant comparator countries. However, despite the gains observed at the national level, significant heterogeneity in vaccination coverage and population health outcomes persist across geographic regions, socioeconomic groups, and individual vaccines within India. Moreover, India is expected to face considerable challenges in maintaining its vaccination momentum, as the country transitions out of Gavi support and contemplates introducing newer, relatively more expensive vaccines that are either now available or are expected to become available in the near future.

Recent advancements in thinking about and evidence on the full value of vaccination suggest that much more than India's population health hangs in the balance as the Central and State Governments determine the country's immunization policy moving forward. Indeed, it is now well established that the good health delivered by vaccination offers not only intrinsic value, but also instrumental value for other forms of economic and social wellbeing. To be fully rational, immunization policies in India should be informed by the full health, economic, and social impacts of vaccination.

Keywords: Vaccination, vaccines, immunization, value of vaccination, broader social and economic impacts of vaccination, India, Gavi transition.

INTRODUCTION

Vaccination has long been regarded as a key pillar of public health. Considered one of the top inventions of the modern era[1] and one of the world's most cost-effective health interventions, immunization currently prevents over 2 million deaths every year.[2]

In India, deaths among children under the age of five due to conditions potentially averted through vaccination have fallen on the order of 50–90% since 2000. For example, the number of under-five deaths due to measles and pertussis fell by 83% and 71%, respectively, between 2000 and 2017,[3] while the rate of under-five pneumonia deaths fell by 57% between 2000 and 2015.[4] Overall, the Indian under-five child mortality rate fell by 59% between 2000 and 2019, and life expectancy increased by more than 7 years.[5] Without a doubt, a considerable portion of these gains can be attributed to vaccination.

Indeed, India has made significant advances in terms of both vaccination introduction and coverage in recent years. Five new vaccines, as well as a booster dose of measles-containing vaccine (MCV), have been introduced into the country's Universal Immunization Program (UIP) since 2000. Over the same time period, coverage of the third dose of the diphtheria, tetanus, and pertussis (DTP3) vaccine—considered to be the standard indicator of immunization coverage by vaccination and global health experts—increased by more than 30 percentage points.[6] DTP3 coverage reached 89% in 2018, placing India above the global average and nearly on par with high-income countries such as Canada, Finland, and Iceland.[6]

Despite these recent gains, India faces an unfinished agenda when it comes to immunization and promoting the health of its population. Significant heterogeneity in coverage exists across states, certain subpopulations, and individual vaccines. Distressing numbers of children remain without any vaccination, and equity issues are a concern.

External partners—especially Gavi, the Vaccine Alliance, the World Health Organization (WHO), and the United Nations Children's Fund—have played a significant role in supporting vaccination in India. External partners collectively accounted for roughly a fifth of total immunization program spending from 2017 to 2018. Gavi accounted for the majority of external partner donations and contributed more than US$ 300 million for immunization assistance and health systems strengthening between 2000 and 2015.[7,8] With economic advancement, however, India has now crossed Gavi's eligibility threshold of US$ 1,580 gross national income per capita and is currently undergoing accelerated transition out of Gavi support. Total external donor support is, therefore, expected to be substantially diminished in the near future. Given this new reality, Indian policymakers at both the national and state levels will soon have to make critical decisions about whether, how, and at what level to fund vaccination, including novel and likely comparatively expensive vaccines on the horizon.

In order to ensure these decisions are well-informed and rational, it is critically important for Indian policymakers to understand the full value of vaccination. This paper briefly characterizes vaccination in the Indian context in historical and comparative terms before summarizing recent developments in thinking about and evidence on the full health, economic, and social value of vaccination. The conclusion considers the relevance of this evidence for India and discusses some of the anticipated vaccination-related challenges in coming years.

HISTORICAL BACKGROUND OF VACCINATION IN INDIA

India has an ancient history with regards to vaccination. The practice of smallpox inoculation, which consisted of injecting variolous matter with several tiny jabs of a fine needle into the forearm of an individual, was conducted routinely during the Bengal and Bombay Presidencies in India in the 16th and 17th centuries.[9] Soon after Edward Jenner's discovery of the smallpox vaccine in the late 18th century, doses of that vaccine were deployed in India by 1802.[10] With increasing use of the smallpox vaccine, inoculation fell into disfavor because of the high risks and lower efficacy associated with it compared to vaccination. The earliest vaccination legislation in India was the Vaccination Act of 1880, which was enacted to improve smallpox vaccination rates by providing compulsory vaccination in protective regional "circles" and by outlawing variolation or inoculation.[11]

An outbreak of cholera and plague in India between 1896 and 1907 spurred vaccine manufacturing at the Haffkine Institute in Bombay. By the early 1900s, four vaccines—smallpox, cholera, plague, and typhoid vaccines—were routinely being used in India. Eventually, over the next several decades, the Bacille Calmette-Guérin (BCG) vaccine against tuberculosis, oral polio vaccine (OPV), and MCV were added to the list of available vaccines. Intense smallpox eradication efforts were underway when the WHO launched the Expanded Program on Immunization (EPI) in 1974. India launched its own EPI platform in 1978 that included BCG, OPV, DTP and typhoid-paratyphoid vaccines. This program underwent further changes and reemerged as the UIP in 1985, with a focus on six vaccine preventable diseases (VPDs): (1) measles, (2) pertussis, (3) polio, (4) diphtheria, (5) neonatal tetanus, and (6) tuberculosis.[12,13] By 1990, the UIP was in full force in all districts in India and had the initial target of achieving universal coverage among all infants and pregnant women.

For the next two decades, immunization coverage remained low, and no new vaccines were introduced into the national program, although a number of novel vaccines were licensed and recommended in national programs of other countries. However, India ramped up efforts in the battle against polio; an effective partnership between the WHO and the Government of India resulted in the formation of the National Polio Surveillance Project in 1997, which played a key role in polio eradication in India. In 2002, the hepatitis B (HepB) vaccine was introduced in selected districts as part of a pilot project, and subsequently became the seventh vaccine to be introduced into the UIP in 2011.[14] Also in 2011, the *Haemophilus influenzae* type b (Hib) vaccine was introduced into two southern states; its use was later extended to other states in a phased manner throughout 2015.[15] The introduction of new vaccines into the national immunization schedule is depicted in **Table 1**.

TABLE 1: Vaccine milestones in India.

Year	*Vaccine*	*Milestone remarks*
1985	BCG; diphtheria, pertussis, and tetanus (DPT); OPV; and measles -containing vaccine (MCV)	Universal Immunization Program (UIP) launched with six antigens
2002	Hepatitis B—pilot	Hepatitis B vaccine launched as a pilot program in 33 districts and 14 metropolitan areas
2006–2010	Japanese encephalitis (JE)	JE vaccine added to the UIP in selected endemic districts in a phased manner
2007–2011	Hepatitis B—scale up	Hepatitis B vaccination scaled up to cover 10 additional states of India
2010	Measles-containing vaccine dose 2 (MCV2) + rubella	MCV2 (in the form of measles-rubella vaccine) added to the UIP in 21 states (in the remaining 14 states, a catchup campaign was initiated for children aged 9 months to 9 years)
2011	*Haemophilus influenzae* type b (Hib)[83]	Hib vaccine introduced as the pentavalent (DPT + Hib + HepB) vaccine in two states (Tamil Nadu and Kerala)
2016	Human papillomavirus[84]	Pilot program launched by state governments in Delhi and Punjab
2016–2018	Rotavirus[85]	Introduced in two phases in nine states (Andhra Pradesh, Haryana, Himachal Pradesh, Odisha, Assam, Madhya Pradesh, Rajasthan, Tamil Nadu, and Tripura)
2017–2019	Pneumococcal conjugate vaccine (PCV)[86]	PCV introduced in selected high-burden districts in six states (Bihar, Uttar Pradesh, Haryana, Himachal Pradesh, Rajasthan, and Madhya Pradesh)

(BCG: Bacille Calmette-Guérin; HepB: hepatitis B; OPV: oral polio vaccine)

The constitution of the National Technical Advisory Group on Immunization in 2001 represents another noteworthy milestone in India's vaccination history (John TJ. India's National Technical Advisory Group on Immunisation. Vaccine. 2010;28(Suppl 1):A88-90). Likewise, the establishment of the adverse events following immunization (AEFI) guidelines in 1985 was also important; however, reporting remained suboptimal until 2005 when revised AEFI guidelines were established and disseminated.[16]

Vaccine Campaigns

Japanese encephalitis vaccine campaign: In 2006, following large outbreaks of Japanese encephalitis (JE) in some eastern districts in Uttar Pradesh and Bihar, the Government of India launched an immunization campaign against JE that reached over 9 million children aged 1–15 years living in JE-endemic areas in four states (Uttar Pradesh, Assam, West Bengal, and Karnataka). In 2011, the same vaccine was introduced into routine immunization under the UIP in these endemic districts, with initial JE vaccination scheduled to take place at 9 months of age followed by a booster at 16–18 months of age.[17] Well-designed evaluations of the effectiveness of the campaign and the vaccine use would be helpful in guiding policy.[18]

Polio vaccine campaign: The polio campaign was a successful program that was launched with the help of international collaborations and intersectoral cooperation in India.[19] Since 2004 pulse polio vaccination campaigns have been conducted up to 12 times per year, in conjunction with improved tracking of vulnerable populations and coordinated acute flaccid paralysis surveillance programs.[20] With the early elimination of wild polio virus type 2, the bivalent OPV (bOPV, with both types 1 and 3) was developed and judiciously deployed during the campaigns.

With the last reported cases of wild polio in India in West Bengal and Gujarat in January 2011, India was declared to be polio free by the WHO in March 2014. The health and economic benefits of polio elimination in India using OPV were estimated to be over $1 trillion, when accounting for averted polio incidence, deaths, and disability-adjusted life years (DALYs).[21]

The polio endgame strategy of the Global Polio Eradication Initiative lays out the roadmap to achieving and sustaining a world free of all polioviruses by focusing on three key pillars: (1) eradication, (2) integration, and (3) containment. In pursuance of this polio endgame strategy, the India Expert Advisory Group on polio eradication recommended the addition of a single dose of inactivated polio vaccine to the national immunization schedule, accompanied by a lower intensity of supplemental OPV vaccination campaigns. Budget analyses of this proposed new approach indicate that while the cost of vaccines in the regular immunization program are expected to increase from $20 million to $47 million, the cost of supplemental polio campaigns will decrease from $72 million to $53 million, resulting in a net savings of $6 million.[22]

Mission Indradhanush: In 2014, the Government of India launched Mission Indradhanush, partly to address the country's low "full vaccination" coverage rate (i.e., coverage with full immunization of all vaccines in the UIP) of 65%, reported in 2013. Its goal was to achieve 90% coverage of full vaccination by 2020.[23,24] The campaign targeted vulnerable children residing in hard-to-reach areas with poor healthcare access. Implementers focused on high-disease burden districts across 27 states, covering about 528 districts in a phased manner. Between April 2015 and July 2017, the program vaccinated an additional 26 million children and 7 million pregnant women.[23] While this translated into an increase in immunization coverage in the range of 6–7 percentage points, these improvements were deemed insufficient for achieving the campaign's targets for 2020. This led policymakers in 2017 to initiate the Intensified Mission Indradhanush, designed to target specific districts and urban areas with known low immunization coverage. The intensified campaign used additional strategies of accurate head counting of individuals to reach populations at high risk, mobilizing teams of community health workers and supervisors, and involving nonhealth sectors to help address social and knowledge barriers among communities.[23] The program's prospects rested on identifying all potential beneficiaries using the head counting approach. This was conducted via door-to-door household surveys in all selected districts, including remote areas (Travasso C. Mission Indradhanush makes vaccination progress in India. BMJ. 2015;351:h4440). These household surveys were conducted by facility staff (auxiliary nurse midwives), community-based workers (accredited social health activists), and nonhealth workers (anganwadi workers), and were validated by supervisors for completeness and quality. The intensified campaign's impact on disease burden and its cost-effectiveness have yet to be adequately assessed.

Measles-rubella vaccine campaign: In response to the high mortality attributed to measles infection, as well as the recognition of the prevalence of birth defects caused by congenital rubella, the Government of India initiated a measles-rubella (MR) vaccination campaign in 2017. This campaign initially targeted three states and two union territories and aims, eventually, to increase to coverage across the entire country.[25,26] A recent analysis of nationally representative survey data indicated that measles deaths have decreased by 27% in the campaign states compared to the noncampaign states.[27]

DESCRIPTIVE ANALYSIS OF VACCINE COVERAGE IN INDIA

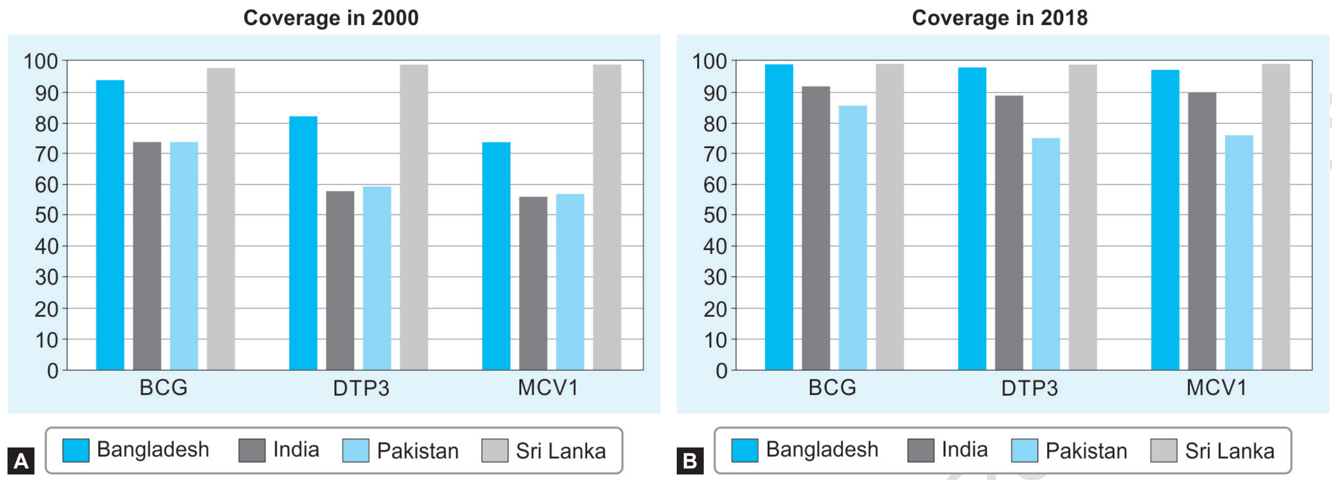
India's various vaccination campaigns and initiatives have resulted in considerable progress over the past two decades with respect to increasing coverage of both traditional and new vaccines **(Table 2)**. India has managed to catch up to, or even overtake, other countries—such as Bangladesh, China, Indonesia, Sri Lanka, and Vietnam—that stood well ahead in terms of coverage at the beginning of the 21st century **(Figs. 1 and 2)**. Still, gaps between India and some of its neighbors remain. In addition, significant heterogeneity exists with respect to coverage rates within India. This section explores recent trends and patterns in India's immunization coverage.

Since 2000, coverage of the first dose of MCV (MCV1) has increased by 61 percentage points, coverage of DTP3 by 53 percentage points, and coverage of BCG by 24 percentage points.[6] In the last decade, new vaccines for HepB, Hib, rotavirus, and pneumococcal disease have been introduced. Disparities in coverage rates of these vaccines partly reflect their varying dates of introduction: Coverage rates of the third dose of the HepB (HepB3) vaccine, which

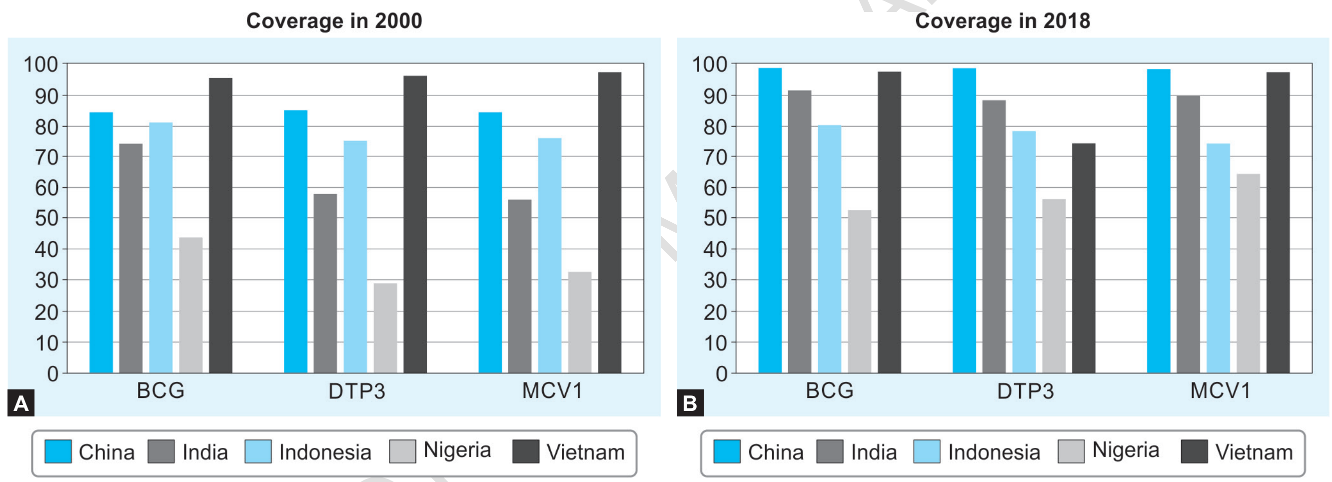
TABLE 2: Immunization coverage in India, 2000–2018.[6]

Antigens/vaccines in use	*Coverage (%)*		
	2000	*2010*	*2018*
BCG	74	89	92
DTP3	58	79	89
HepB3	–	38	89
MCV1	56	82	90
MCV2	–	–	80
PAB	85	87	90
Pol3	85	76	89
Rotavirus	–	–	35
Hib3	–	–	89
PCV3	–	–	6

(BCG: Bacille Calmette-Guérin; DTP3: third dose of diphtheria, tetanus, and pertussis; HepB3: third dose of hepatitis B; Hib3: *Haemophilus influenzae* type b third dose; MCV1: measles-containing vaccine dose 1; MCV2: measles-containing vaccine dose 2; PAB: protection at birth; PCV3: third dose of pneumococcal conjugate vaccine; Pol3: third dose of polio)



Figs. 1A and B: Comparing India's immunization coverage to that of its neighbors, in 2000 and 2018.[6] (BCG: Bacille Calmette-Guérin; DTP3: third dose of diphtheria, tetanus, and pertussis; MCV1: measles-containing vaccine dose 1)



Figs. 2A and B: Immunization coverage in India and in international comparators, in 2000 and 2018.[6] (BCG: Bacille Calmette-Guérin; DTP3: third dose of diphtheria, tetanus, and pertussis; MCV1: measles-containing vaccine dose 1)

was introduced in 2002–2003 and scaled up in 2011, and of the Hib vaccine, which was introduced in 2011, were both close to 90% in 2018. By contrast, coverage rates of rotavirus (Rota) vaccine, which was introduced in 2016, and PCV, which was introduced in 2017, were only 35% and 6%, respectively, at that time.

Successful immunization campaigns targeting traditional vaccines have allowed India to reduce the coverage gap with respect to its neighbors and other countries with similar characteristics (e.g. stage of development or population size). For example, in 2000, DTP3 coverage was more than 40 percentage points higher in Sri Lanka than in India, while that gap had been reduced to 10 percentage points by 2018. In 2000, MCV coverage was 40 percentage points higher in Vietnam than in India, while in 2010 it was only 9 percentage points higher.[6] **Figures 1 and 2** document the progress in vaccination coverage in India compared with other countries, and India has clearly outperformed some of its comparators. However, these figures also show that there is still a considerable gap in vaccination coverage between India and selected countries (see, for example, Bangladesh, Sri Lanka, Vietnam, and China). Similar patterns can be seen in the immunization coverage of new vaccines. Coverage in India is increasing, but it is still lower than in countries such as China or Bangladesh **(Table 3)**.

TABLE 3: Immunization coverage in India and other countries, 2018.[6]

	HepB	*Rota*	*PCV3*	*Hib3*
Bangladesh	98	–	97	98
China	99	–	–	99
India	89	35	6	89
Indonesia	79	–	8	79
Nigeria	57	–	57	57
Pakistan	75	58	79	75
Sri Lanka	99	–	–	99
Vietnam	75	–	–	75

(HepB: hepatitis B; Hib3: *Haemophilus influenzae* type b third dose; PCV3: third dose of pneumococcal conjugate vaccine)

National averages conceal large variation in coverage rates across Indian states.[28] For example in 2015-2016, fewer than 40% of children in Nagaland and Arunachal Pradesh were fully vaccinated under the UIP (i.e., received all of BCG, three doses of polio and DTP vaccines, and a first dose of MCV), while in Goa and Punjab almost 90% of the children were fully vaccinated **(Table 4)**.[29] Low vaccination coverage is concentrated especially in the northeastern and western parts of India. There is also considerable heterogeneity at the district level. For instance, in 69 out of 640 Indian districts, more than 95% of children received all three doses of the DTP vaccine (with 10 districts achieving 100% coverage), whereas in 28 districts DTP3 coverage was less than 50% **(Table 5)**.[5]

TABLE 4: Vaccination coverage by state and union territory, 2015–2016.[29]

	BCG	*DTP*	*MCV*	*HepB*	*Full 8*	*No vaccination*
National average	91.9	78.4	72.8	81.1	62	6
Andaman and Nicobar Islands	87.4	83.5	76.4	73.2	73.2	12.6
Andhra Pradesh	97.2	89	72.3	89.4	65.2	2.3
Arunachal Pradesh	70.9	52.3	53.7	54.6	38.2	19.7
Assam	82.3	66.5	56	71.4	47.1	13.9
Bihar	91.6	80.1	72.9	79.4	61.7	6.5
Chandigarh	95.9	95.9	79.5	95.9	79.5	4.1
Chhattisgarh	98.4	91.4	81.7	93.9	76.4	0.8
Dadra and Nagar Haveli	88.9	73.3	58.1	81.7	43.2	3.4
Daman and Diu	84.3	74	74.4	79.1	66.3	15.7
Delhi	95	84.8	79	91.1	68.8	2.9
Goa	100	94.2	92.9	96.5	88.4	0
Gujarat	87.9	72.7	62.3	75	50.4	8.7
Haryana	92.8	76.5	75.3	79	62.2	6.3
Himachal Pradesh	94.8	85	82.4	87.5	69.5	2.7
Jammu and Kashmir	95.6	88.1	83.8	86.2	75.1	3.5
Jharkhand	95.8	82.3	73.8	82.6	61.9	2.9
Karnataka	92.5	77.9	74.6	82.4	62.6	6.2
Kerala	98.1	90.4	88.5	89.4	82.1	1.7
Lakshadweep	100	95.1	92.1	93.7	89	0
Madhya Pradesh	91.6	73.4	63.6	79.6	53.6	6.1
Maharashtra	90	74.8	67	82.8	56.2	8.2
Manipur	91.2	77.8	76.6	74.2	65.8	5.3
Meghalaya	85.9	73.9	70.9	71.8	61.4	11.6
Mizoram	75.3	61.9	61.8	61.3	50.7	22.1
Nagaland	68.1	51.6	52.1	50.1	35.4	19.1

Contd…

Contd…

	BCG	*DTP*	*MCV*	*HepB*	*Full 8*	*No vaccination*
Odisha	94.1	89.2	82.8	87.9	78.6	5.8
Puducherry	99.9	96	95.4	95.4	91.2	0.1
Punjab	98.2	94.5	93.7	93.1	89	1.7
Rajasthan	88.8	71.6	65.4	78.1	54.8	7.4
Sikkim	98.9	93	87.7	93.3	83	1.1
Tamil Nadu	94.9	84.5	82.3	85.1	69.7	3.4
Telangana	97.4	87.9	75.2	90.1	67.5	1.1
Tripura	82.4	71.1	70.1	69.7	54.5	13
Uttar Pradesh	87.6	66.5	68.3	70.8	51.1	8.7
Uttarakhand	92.8	79.9	67.9	80.4	57.6	5.2
West Bengal	97.5	92.7	87.9	92.8	84.4	2

(BCG: Bacille Calmette-Guérin; HepB: hepatitis B; DTP: diphtheria, tetanus, and pertussis; MCV: measles-containing vaccine)
Note: The highest-performing states (above 80%), with respect to full immunization coverage, are highlighted in blue, while the lowest-performing states (below 50%) are highlighted in red.

TABLE 5: Indian districts with lowest DTP3 coverage 2015–2016.[29]

District	*State*	*Third dose of diphtheria, tetanus, and pertussis (DTP3)*
Bahraich	Uttar Pradesh	15.4
Balrampur	Uttar Pradesh	18.2
Dhubri	Assam	30.7
East Kameng	Arunachal Pradesh	17.4
Kurung Kumey	Arunachal Pradesh	28.6
Longleng	Nagaland	28.2
Mewat	Haryana	23.8
Mon	Nagaland	30
Shravasti	Uttar Pradesh	27.4
Upper Subansiri	Arunachal Pradesh	31.1

Note: The districts with 100% coverage of DTP are: Ambala (Haryana), Bankura (West Bengal), Dhenkanal (Odisha), Faridkot (Punjab), Hugli (West Bengal), Kapurthala (Punjab), Kottayam (Kerala), Moga (Punjab), Nadia (West Bengal), and Panchkula (Haryana).

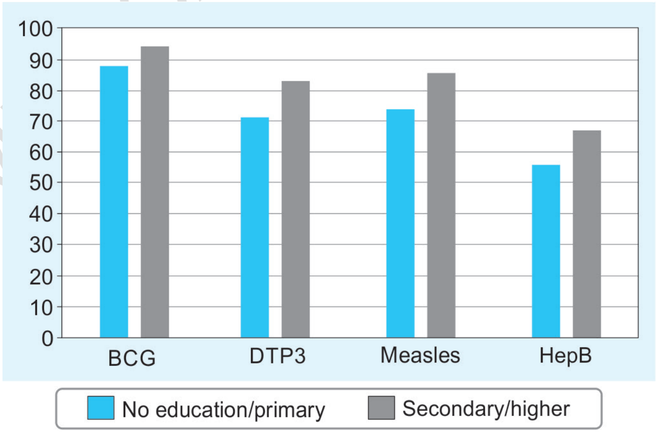


Fig. 3: Vaccination coverage by mother's education level, 2015–2016.[30] (BCG: Bacille Calmette-Guérin; DPT3: third dose of diphtheria, pertussis, and tetanus; HepB: hepatitis B)

Other axes of heterogeneity in vaccination coverage concern household socioeconomic status and birth order.[30] For instance, children whose mothers have no education or only primary education are less likely to receive BCG, DTP, MCV, and HepB vaccines than children whose mothers have received at least some secondary or higher education **(Fig. 3)**. Moreover, children with a later birth order are at higher risk of contracting infectious diseases than those with earlier birth order **(Fig. 4)**. For example, the probability that a fifth-born child completes DTP vaccination is 20% lower than the probability that a first-born child does. Historical disparities between rural and urban areas and between boys and girls have abated, although they may still exist at the state level.[31,32] For instance, the urban-rural coverage gap in DTP3 coverage is 2.5 percentage points at the national level, but in a few states it is larger than 10 percentage points **(Fig. 5 and Table 6)**.

THE FULL HEALTH, ECONOMIC, AND SOCIAL VALUE OF VACCINATION: CONCEPT AND SELECTED EVIDENCE

Vaccination has long been appreciated and valued in terms of the benefits it yields for a relatively narrow set

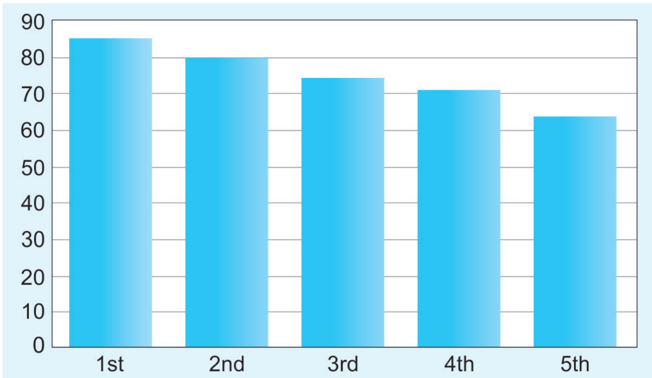


Fig. 4: Coverage of three doses of DTP vaccine by birth order, 2015–2016.[30]

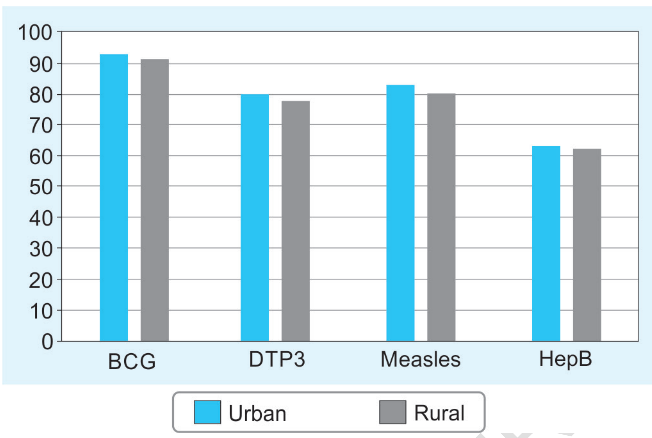


Fig. 5: Vaccination coverage by place of residence, 2015–2016.[30] (BCG: Bacille Calmette-Guérin; DPT3: third dose of diphtheria, pertussis, and tetanus)

TABLE 6: States where the urban-rural gap in DTP vaccine coverage is higher than 10%.[30]

	Third dose of diphtheria, tetanus, and pertussis (DTP3)	*Urban-rural gap*
National average	78.4	2.5
Assam	66.5	18.2
Madhya Pradesh	73.4	10.1
Manipur	77.8	10.6
Meghalaya	73.9	16.4

of health-centric outcomes. In recent years, however, economists and global health experts have come to understand that health interventions such as vaccination confer a much broader set of health, economic, and social benefits.[33,34] Moreover, these broad benefits accrue not just to the individual directly protected through vaccination, but also, to varying degrees, to different stakeholders within society. **Table 7** lays out a general framework for the most significant categories of the full health, economic, and social impacts of vaccination, as well as the distribution of those impacts. This section articulates the rationale for each of those categories and briefly reviews recent evidence on a selection of vaccination's broad benefits. It should be noted that certain proposed broad benefits of vaccination have been studied much more intensively than others (e.g. vaccination's implications for school attainment and cognition in children have received significant attention). Where empirical evidence exists, it tends to strongly support the hypothesis that vaccination's full value far exceeds its narrow value, and several studies specifically offer support for this hypothesis in the Indian context.

To be sure, any appraisal of vaccination's value must include its "narrow" health benefits, which have long been appreciated and included in economic evaluations. These narrow health benefits include directly preventing, in the immunized, morbidity, and mortality due to incident cases of VPD. They also include healthcare cost savings stemming from the decreased need for treatment in these individuals. Of course, any adverse effects of vaccination must also be taken into account.

Vaccination also provides "broader" health benefits that have not traditionally been appreciated. In addition to reducing morbidity and mortality by directly preventing cases of disease, vaccination can yield further direct health benefits by reducing the severity of illness when infections do occur in vaccinated individuals. Additionally, there is some evidence that certain vaccines provide some protection against a broad array of non-target pathogens (e.g., MCV appears to protect against deletion of immune memory that occurs with measles infection). Also at the individual level, vaccination can help prevent secondary health effects of VPDs; secondary effects include nosocomial infections in hospitalized patients as well as long-term sequelae, such as altered lung function in children who have suffered pneumonia or hearing and vision loss in children who have suffered meningitis. For both individuals and their families, vaccination can help prevent the mental health toll that severe illness can exact; somatic disease may be accompanied by depression and anxiety in the afflicted and their loved ones. Finally, for individuals, improved health offers intrinsic value insofar as healthier people enjoy greater utility and happiness, beyond what may be derived from any instrumental effects on, for example, economic well-being.

TABLE 7: Full health, economic, and social impacts of health conditions and their distributions.

Categories	*Individual*	*Family/Household*	*Society (health sector)*	*Society (nonhealth sector)*
Direct health effects: • Morbidity and mortality • Disease severity • Non-specific protection • Adverse effects of treatment	✓	–	–	–
Secondary health effects (physical): • Comorbidities • Nosocomial infections • Long-term health sequelae	✓	–	–	–
Mental health effects	✓	✓	–	–
Intrinsic value of good health	✓	–	–	✓
Healthcare costs	✓	✓	✓	✓
Cost of caregiving	✓	✓	✓	✓
Transportation costs	✓	✓	–	–
Labor participation, hours, and income	✓	✓	–	✓
Educational attainment, school attendance, and cognition	✓	✓	–	✓
Fiscal impact: Tax receipts	–	–	–	✓
Fiscal impact: Government spending	–	–	✓	–
Wealth/savings	✓	✓	–	✓
Social protection	✓	✓	✓	✓
Risk reduction and peace of mind	✓	✓	–	✓
Social equity	–	–	–	✓
Intergenerational effects	–	✓	–	✓

At a societal level, vaccination's health benefits are amplified by the phenomenon of community (or "herd") protection, in which unvaccinated or undervaccinated individuals in the community are protected by the effects of vaccination in interrupting the transmission of pathogens. Vaccination can also have a significant positive impact on antimicrobial resistance (AMR).[35] Vaccination counters AMR directly by preventing resistant cases of infection, as well as indirectly by decreasing infectious disease burden and therefore reducing the overall need for antimicrobial treatment. This, in turn, reduces the evolutionary pressure toward developing resistance both in the microbes targeted by the treatment and in bystander colonizing species.

Healthcare cost savings from vaccination also extend beyond those traditionally captured in narrowly focused appraisals of its value. In addition to reducing treatment costs for all of the potential health burdens enumerated above, vaccination provides savings with respect to the costs of formal and informal caregiving and transportation. Particularly in rural areas of less-developed parts of the world, accessing care can be costly in terms of both time and money, as sick individuals and their family members commonly have to travel for many hours to reach quality emergency medical services.

Not only does vaccination yield health benefits and health-related cost savings, but an increasing amount of evidence supports the notion that vaccination is also a productive investment that enhances individual and collective economic well-being. Vaccinated children tend to attend school more regularly, attain higher levels of schooling, and have better cognitive function on average than their unvaccinated and less-healthy counterparts. This ultimately translates into greater productivity and higher income upon reaching adulthood. By the same token, when working-age adults are protected from VPDs, they are more likely to participate in the workforce and tend to work for more hours and more productively than they would otherwise, further boosting income. And older adults who have retired from the paid workforce may be more likely to partake in economically valuable, unpaid nonmarket activities, such a volunteering or raising grandchildren, if they remain healthy.

Increased income stemming from educational, labor force participation, and productivity gains due to vaccination can lead to greater accumulated wealth and savings at the household level. Also within households, vaccination may yield benefits in terms of risk reduction and improved peace of mind, as families face decreased anxiety over the prospect of catastrophic health and financial consequences from VPDs. Also by protecting against catastrophic healthcare spending, vaccination can have a social protection effect, in which the collective economic vulnerability and risk of poverty are reduced. Finally, with respect to economic benefits, increased individual and household income may aggregate up to have fiscal impacts, such as increased tax receipts and reduced government spending, at the macroeconomic level.

Vaccination's social benefits include what are called intergenerational effects. For example, thanks to protection against cervical cancer granted by vaccination against human papillomavirus (HPV), more mothers will survive to care for their children. Finally, insofar as vaccination prevents diseases that tend to disproportionately affect the worse off, it can promote social equity.

In principle, all of vaccination's various health, social, and economic benefits can be measured and expressed in monetary terms through some form of economic assessment, such as cost-benefit analysis or cost-effectiveness analysis done at the societal level.[36] Doing so would allow for one-to-one comparisons of the value of vaccination versus other potential uses of social resources, such as investments in education or infrastructure. The economic tools and technical expertise required for such assessments exist. In some cases, however, quality data are lacking. Nevertheless, a number of analyses designed to estimate elements of vaccination's full value have already been conducted. Here, we briefly summarize recent evidence on the full health, economic, and social value of vaccination, with a special emphasis on analyses related to the Indian context.

Selected Evidence

Reduced Healthcare Costs and Protection against Catastrophic Spending

In low- and middle-income countries (LMICs), medical expenses are heavily borne out of pocket by the consumer. In Southeast Asia (as defined by the WHO), which includes 11 countries including India, Bangladesh, and Indonesia, 44% of healthcare expenditure in 2018 was financed privately.[37] In India, where the burden of many VPDs is the highest in the world, 65% of all health expenditure remains private.[38,39] Catastrophic health expenditure, defined in terms of out-of-pocket medical expenses as a large proportion of a household's purchasing power (e.g. more than 25%), is known to push millions of people into poverty in India and around the world every year.[40] Many infectious diseases are considered to be diseases of poverty—they are positively associated with low income, and lack of access to water, sanitation, hygiene, and basic healthcare. The disease and economic burden of VPDs are higher in LMICs than in high-income countries and within LMICs, they are often highest in the poorest segment of the population. A 2018 study estimated that the measles, rotavirus, and pneumococcal conjugate vaccines could avert $4.6 billion (2016 US$) in out-of-pocket medical expenses in 41 Gavi-eligible LMICs during 2016–2030.[42] The authors also estimated that the vaccines could help prevent 12.6 million cases of catastrophic health expenditure due to VPDs.[41] For the measles vaccine, 75% of averted catastrophic health expenditure cases were from the lowest wealth quintile.

Productivity and Income

In addition to averting out-of-pocket medical expenses, vaccination can prevent wage loss and provide economic productivity benefits,[41-48] which have been analyzed by several cost-effectiveness, extended cost-effectiveness, and cost-benefit studies.[33,34,49-52] A 2012 systematic review study of 23 vaccines in 52 LMICs found 86% of the vaccines to be highly cost-effective at lower than $1,000 per DALY.[49] Another study examined 10 vaccines—for Hib, HepB, HPV, JE, measles, *Neisseria meningitidis* serogroup A, rotavirus, rubella, *Streptococcus pneumoniae*, and yellow fever—in 94 LMICs, and found that their economic benefits during 2011–2020 would be 16 times their cost when averted medical expenses were considered, and 44 times their cost when gains in economic productivity were considered.[52] Another study of these vaccines in 73 LMICs estimated a social and economic value of $820 billion (2010 US$) during 2001–2020.[50] Several other studies of individual vaccines such as those for rotavirus, Hib, dengue, *pneumococcus*, and seasonal influenza have estimated high levels of economic benefits in LMICs.[41,42,45,53-63] Finally, a recent study drawing on data from Bihar, New Delhi, Maharashtra, and Tamil Nadu estimated that scaling up coverage of Hib, pneumococcal conjugate, and rotavirus vaccines could yield over US$ 1 billion in economic benefits per year when accounting for averted productivity loss due to disability and informal caretaking in addition to treatment cost savings.[64]

Cognition and Schooling

Infectious diseases in early childhood can result in stunting, which is known to be negatively associated with cognitive development and schooling outcomes.[65-67] In particular, measles infection can damage children's protective immune memory for up to 3 years following an episode, making them vulnerable to other infectious diseases and diminishing their health and cognitive potential.[68-71] In 2004, 279 million children under five years of age worldwide—primarily based in sub-Saharan Africa and South Asia—were projected to fail to reach their developmental potential due to early-life exposure to poverty, undernutrition, diseases, and lack of care.[72] Although the number of at-risk children in South Asia decreased substantially by 2010, there were still 249 million at-risk children across the world.[72] These children are likely to have lower cognitive development, attain fewer schooling grades, have lower income and higher fertility in the future, and provide fewer resources toward the growth and development of their own children.[73] In addition to proper nutrition and nurturing, vaccines can prevent episodes of VPDs and may thereby improve health, cognitive, and schooling outcomes, and help break the intergenerational cycle of poverty.

A 2011 study used longitudinal data from the Philippines and found that full immunization in the first 2 years of life improved cognitive test scores of 10–11-year-old children by about 0.5 standard deviations.[74] Another study found that a phased introduction of measles vaccine among children in the Matlab district of Bangladesh increased school enrollment rate by 7.4 percentage points among 8–16-year-old boys, but had no effect among girls.[75] A South African study compared siblings and found that 6–11-year-old children who received MCV attained 0.2 more schooling grades on average as compared with their siblings.[76] A 2019 longitudinal study in Ethiopia, India, and Vietnam found that children who received MCV between 6 and 18 months of age had, in comparison with those who did not receive MCV, 0.1–0.2 higher anthropometric z-scores, 1.7–4.5 percentage points higher scores on standardized cognition tests, and 0.2–0.3 additional schooling grades at ages 7–8 and 11–12.[77]

A study among Indian children has linked the receipt of Hib vaccine before age 6 with 0.2–0.3 higher height-for-age z score, 3–5 percentage points higher scores on standardized cognition tests, and 0.2 higher schooling grades at ages 11–15.[78] Another longitudinal Matlab study found that exposure to tetanus immunization in utero increased schooling attainment by 0.3 years.[79] Finally, a study has associated exposure to India's national vaccination program during early life with 0.2 additional schooling grades among adults.[80]

CONCLUSION

Failure to account for the full health, economic, and social value of vaccination has led to vaccination's being historically undervalued globally and in India. This undervaluation has likely translated into underinvestment both in immunization in particular and in the health sector as a whole, leaving potential gains in health and other forms of well-being on the table.

Despite this underinvestment, India has nevertheless made significant advances in both vaccination and related health outcomes in recent years. Mission Indradhanush and Intensified Mission Indradhanush, for example, played a significant role in increasing immunization coverage and in progressing toward India's target of fully immunizing 90% of the population by 2020. India has also made gains in terms of building a formidable vaccines manufacturing industry. The Serum Institute of India is now the world's largest vaccines manufacturer by number of doses produced, and Bharat Biotech developed the rotavirus vaccine used in India, as well as the world's first WHO-prequalified typhoid conjugate vaccine. Several other manufacturers are following suit with innovative vaccine product and delivery design, and India is likely to retain its position as the world's largest exporter of vaccines.

India's advances in the domain of immunization could be jeopardized, however, if the national and state governments do not continue increasing investments in vaccination following Gavi transition. Even investing enough to merely maintain current levels of coverage would mean foregoing considerable societal value and could play a role in perpetuating socioeconomic inequities. India will also have to make decisions concerning a number of new vaccines either currently available or expected to become available over the next few years. These include new vaccines against HPV, cholera, typhoid, dengue, tuberculosis, and potentially group A *Streptococcus* and group B *Streptococcus*.

In addition, immunization programs in India and throughout the world face a number of common challenges to their sustained success. Health systems and health workers face mounting pressure, as they must accommodate an increasing number of vaccines, some of which must be administered outside the bounds of historically typical vaccine schedules. Infrastructural challenges include sustaining cold chain throughout the process of vaccine transport, distribution, and delivery to ensure product safety and effectiveness. Other logistical challenges include maintaining accurate records of administered vaccine doses, especially in areas lacking modern technologies. In many places, weak infectious disease surveillance systems make it difficult to detect outbreaks, which can be a signal of falling vaccination rates for endemic diseases (e.g., measles) or of the need for a concerted vaccine campaign against a nonendemic one (e.g., yellow fever). Finally, vaccine hesitancy and misinformation spread on social media are increasingly creating challenges for immunization coverage. A recent study conducted in slums of Siliguri, India found that a large majority of families were at least somewhat vaccine hesitant.[81]

One piece of good news for India when it comes to vaccination is that immunization programs may benefit from the good fortune of being small-budget relative to the overall health and public sector budgets. In 2017–2018, total spending on vaccination, including donor contributions, represented only 3% of the national health budget.[7,82] India's governmental health expenditure, in turn, only represented 5.1% of all government spending and 1.4% of gross domestic product (GDP).[82] The diminutive size of India's immunization budget means that significant increases in that budget would have a relatively small impact on overall government health spending, which is small itself.

Overall, India is on a strong path when it comes to immunizing its population and promoting the health, economic, and social well-being of its citizens. To continue this trend, however, the Indian Government would do well to dedicate itself to continuing to expand coverage, expand the number of vaccines in the UIP, and expand its vaccines manufacturing industry. All of this must be done while managing Gavi transition and avoiding backsliding as a result. The bottom line is that committing to sustained investment in vaccination may seem costly for India to do, but given all of the health, economic, and social value that immunization is poised to confer on the Indian people, it would likely be more costly not to do.

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