Analysing the Impact of the Polio Eradication Initiative on Routine Immunisation in Uttar Pradesh, India

by

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Abstract

Embedded in the study of interactions between global health initiatives and country health systems, this paper analyses the impact of the Polio Eradication Initiative's (PEI) on the routine immunisation programme in Uttar Pradesh, India.

Applying the policy implementation framework and a mixed-method research design to analyse the PEI's policy to "strengthen routine immunisation," qualitative analysis demonstrates ambiguous translations of programme policies into operational guidelines. Trends in financial resource allocation and vaccine delivery logistics suggest that this ambiguity gives rise to a prioritisation of polio eradication at the expense of routine immunisation strengthening.

This mismatch is reinforced through the quantitative analysis of household survey data from 2002 to 2008 (District Level Household and Facility Survey). Logistic regression analysis suggests that, within Uttar Pradesh, children with a greater exposure to mass polio immunisation rounds had a lower chance to attain full routine immunisation. However, such adverse policy outcomes need not be a general rule as a similar analysis for the state of Bihar yields more encouraging outcomes.

One mechanism underlying these processes and outcomes appears to be the institutionalisation of mandates in programme implementation. In a health system context that assigns dominance to scientific knowledge and to influential stakeholder groups in health agenda-setting and policy-making, the National Polio Surveillance Project emerges as a powerful technical advisory body. However, its primary objective of eradicating poliomyelitis—rather than supporting routine immunisation operations—suggests a likely programme governance bias which contributes to the mismatch between the routine immunisation strengthening policy and its implementation.

This paper suggests that global health initiatives do not leave health systems unaffected, which can potentially undermine the direct effects of the intervention. Policy implementation processes can contribute to such adverse outcomes, albeit their extent merits further investigation. To address the challenges of polio (and soon measles) immunisation in India, participation of non-technical stakeholders such as recipient communities in programme governance is suggested.

Keywords: Global Polio Eradication Initiative, Global Health Initiatives, India, Routine Immunisation, Policy Implementation

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Abbreviations

AFP	Acute Flaccid Paralysis
AIC	Akaike Information Criterion
BCG	Bacillus Calmette-Guérin Vaccine
bOPV	Bivalent Oral Polio Vaccine
CCHFW	Central Council of Health and Family Welfare
CMO	Chief Medical Officer
DLHS	District-Level Household and Facility Survey
DPT	Diphtheria, Pertussis, and Tetanus Vaccine
GBP	Pound Sterling
GHI	Global Health Intervention or Global Health Initiative
GoI	Government of India
GPEI	Global Polio Eradication Initiative
HepB	Hepatitis B Vaccine
IEAG	India Expert Advisory Group
IIPS	International Institute for Population Sciences
INR	Indian Rupee
IPV	Inactivated Polio Vaccine
MoHFW	Ministry of Health and Family Welfare
mOPV	Monovalent Oral Polio Vaccine
NPSP	National Polio Surveillance Project
NRHM	National Rural Health Mission
NTAGI	National Technical Advisory Group on Immunization
OPV	Oral Polio Vaccine
PEI	Polio Eradication Initiative
RHS	Right-hand side
RI	Routine Immunisation, also UIP
SMNet	Social Mobilisation Network
SR	Sub-Region
tOPV	Trivalent Oral Polio Vaccine
TT	Tetanus toxoid
UIP	Universal Immunisation Programme (India), also RI
UNCIEF	United Nations Children's Fund
UP	Uttar Pradesh
WHA	World Health Assembly
WHO	World Health Organisation
WHO MPSCG	WHO Maximizing Positive Synergies Collaborative Group

1 Introduction and Background

Embedded in the study of interactions between global health initiatives and country health systems, this paper analyses the impact of the Polio Eradication Initiative's (PEI) on the routine immunisation programme in Uttar Pradesh, India. Global public health in recent decades has increasingly emphasised coordinated efforts to eradicate, eliminate, or control diseases and other health problems. Such efforts are referred to as global health interventions or initiatives (GHIs). To date, more than 100 such programmes provide donor-generated funding of billions of dollars each year and are directed at health problems as diverse as blindness, nutrition, or malaria (WHO MPSCG, 2009:2137-2139). One example of these global health interventions is the Global Polio Eradication Initiative (GPEI) and its Indian pendant, the Indian Polio Eradication Initiative (PEI). The global polio eradication activities have been most extensive in India, where the success of eliminating poliomyelitis has materialised only very recently.

The analytical interest in global health interventions is based on their characteristic *integration* into and *interaction* with country health systems (Balabanova et al., 2010:6; Biesma et al., 2009:240; Cavalli et al., 2010:1; WHO MPSCG, 2009:2140). Such interaction between the Polio Eradication Initiative and the Indian health system can be exemplified through the Indian routine immunisation (RI) or Universal Immunisation Programme (UIP), for at least three reasons. Firstly, India had already been carrying out polio immunisation 20 years before the PEI under the routine immunisation programme (Bhattacharya and Dasgupta, 2009:1181).[1] The UIP therefore is a visible and established component of the Indian health system and had already matured when the polio eradication programme was introduced. Secondly, despite its emancipation into a separate national programme, polio vaccination has also remained part of the routine immunisation programme, making routine polio immunisation a complementary strategy to eradicate polio. Thirdly, an *explicit* link exists between polio eradication as GHI and routine immunisation as part of the Indian health system: The constituent document of the GPEI (WHA Resolution 41.28) notes, "Efforts to eradicate poliomyelitis serve to *strengthen other immunization and health services*" (WHA, 1988:1; emphasis added). Therefore, in investigating the interaction between the PEI and the Indian health system, the link to the routine immunisation programme is worthy of academic scrutiny.

In the following, selected features of the Polio Eradication Initiative and the Indian routine immunisation programme are outlined to prepare the analysis (Table 1). Figure 1 depicts a schematic overview of the organisational structures of both programmes. As centrally sponsored health programmes, both are managed by the Ministry of Health and Family Welfare's (MoHFW) national immunisation cell and both have central technical advisory committees. The PEI receives technical advisory from the India Expert Advisory Group (IEAG), comprising representatives from various stakeholders including the Indian government who meet on a semi-annual basis to review programme progress and provide strategic recommendations. The Universal Immunisation Programme is advised by the National Technical Advisory Group on Immunisation (NTAGI), which partly receives inputs

[1] The World Health Assembly (WHA) adopted the Expanded Programme on Immunisation (later UIP) in 1974 with resolution WHA27.57, calling for national immunisation programmes against diphtheria, pertussis, tetanus, measles, poliomyelitis, tuberculosis, smallpox, and other diseases (Litsios, 2008:191).

from the IEAG but meets on a less frequent basis (John, 2010:A89-A90).

Through the joint management (and thus ownership) by the MoHFW, the responsibility of implementing both programmes falls on the Indian states and their health administration. Although this means that immunisation officers on the state, district, and sub-district level are responsible for planning both routine immunisation and polio eradication activities, the PEI support structures deviate from RI. Specifically, the polio programme enjoys the assistance from the National Polio Surveillance Project (NPSP) and UNICEF, both acting as implementing partners: the NPSP, a collaborative institution between the Indian government and the World Health Organisation, provides technical advisory and surveillance intelligence. UNICEF manages the so-called Social Mobilisation Network (SMNet) in Uttar Pradesh and Bihar to support the programme implementation through education, communication, and awareness activities (NPSP, 2006:8-9; Saxena, 2009:23). Besides, steering committees and task forces on all levels of the implementation chain facilitate the operational planning and execution of supplementary immunisation activities in the PEI (NPSP, 2006:8-10).

Furthermore, main differences in service delivery exist. Routine immunisation service delivery is conducted through regularly scheduled outreach sessions in villages and at health facilities (e.g., day-long activities, twice per week). In contrast, the Indian polio eradication efforts utilise national and sub-national immunisation days and mop-up campaigns solely dedicated to polio immunisation in addition to the on-going routine immunisation (6- to 11-day immunisation activities between 2 and 12 times per year; NPSP, 2011: "Eradication Strategy"). Although the programmes differ in their service delivery approach, the PEI relies largely on the same implementation personnel of the health system that also carries out routine immunisation (besides voluntary vaccinators and the implementation partners' staff).

Table 1. Schematic Comparison of Routine Immunisation and Polio Eradication.

	Universal Immunisation Programme (UIP)	Polio Eradication Initiative (PEI)
Objective	Every child is immunised with all recommended antigens[a]	Elimination of wild poliovirus and associated cases of clinical poliomyelitis
Target	Set of diseases (rather than patient): Tuberculosis, poliomyelitis, diphtheria, pertussis, tetanus, hepatitis B,[b, c] measles, Japanese encephalitis[c]	One disease: poliomyelitis
Administrative Structure	National programme: Policy-making centralised, integrated into National Rural Health Mission, technical advisory through National Technical Advisory Group on Immunization (NTAGI)	National programme: Policy-making centralised, integrated into National Rural Health Mission, technical advisory through separate committees and India Expert Advisory Group (IEAG), Global Polio Eradication Initiative (GPEI) as international coordinating body
Implementation Structure	Integrated: Implementation planning through health administration, dedicated immunisation officers	Primarily integrated: Implementation planning through health administration, dedicated immunisation officers, dedicated micro-planning and review processes, technical support through National Polio Surveillance Project (NPSP), social mobilisation support through UNICEF[d]
Service Delivery	Primarily integrated: Vaccine delivery through health workers in health centres and hospitals, partially campaign and outreach mode (biweekly sessions), supplemented by private sector (10-15% of administered vaccines)	Primarily freestanding: Vaccine delivery through health workers and volunteers in dedicated mass immunisation campaigns (6 to 11 days, up to 12 times per year), supplemented by routine immunisation of polio
Polio Vaccine Strategy[e]	• Trivalent OPV (from inception onwards) • Inactivated polio vaccine (recommended by Indian Academy of Pediatrics to private practitioners)	• Trivalent OPV (from inception onwards) • Monovalent OPV (adopted 2005) • Bivalent OPV (adopted 2010)
Target Population	All infants and children under 5 years of age in India[f]	All infants and children under 5 years of age in India
Temporal Scope	Continuous: according to national immunisation schedule	Time-bound: dependent on achievement of programme objectives
Budgeting Process	Integrated into budget of National Rural Health Mission 2005-2012; long-term budgeting approach (continuous programme); domestically funded	Integrated into budget of National Rural Health Mission 2005-2012; short-term budgeting approach (time-bound programme); partly externally funded
Monitoring and Surveillance	Monitoring and surveillance at primary health centre level; recently introduced monitoring of vaccine-preventable diseases and of adverse effects following immunisation	Dedicated polio immunisation round monitoring; separate AFP (acute flaccid paralysis; i.e., symptom) surveillance structure with dedicated surveillance officers

Source: Own elaboration, based on Criel et al. (2004); Dasgupta (2006:293); GoI (2004, 2010); MoHFW (2005a, 2008, 2011b, 2011c); NPSP (2006, 2011); Planning Commission (2008); WHO (2011d), Yewale et al. (2011:47-50); interviews and field notes.

Note. Current programme characteristics.

[a]This also includes administration of Vitamin A and zinc supplements.

[b]Hepatitis B vaccines are administered together with DPT vaccines.

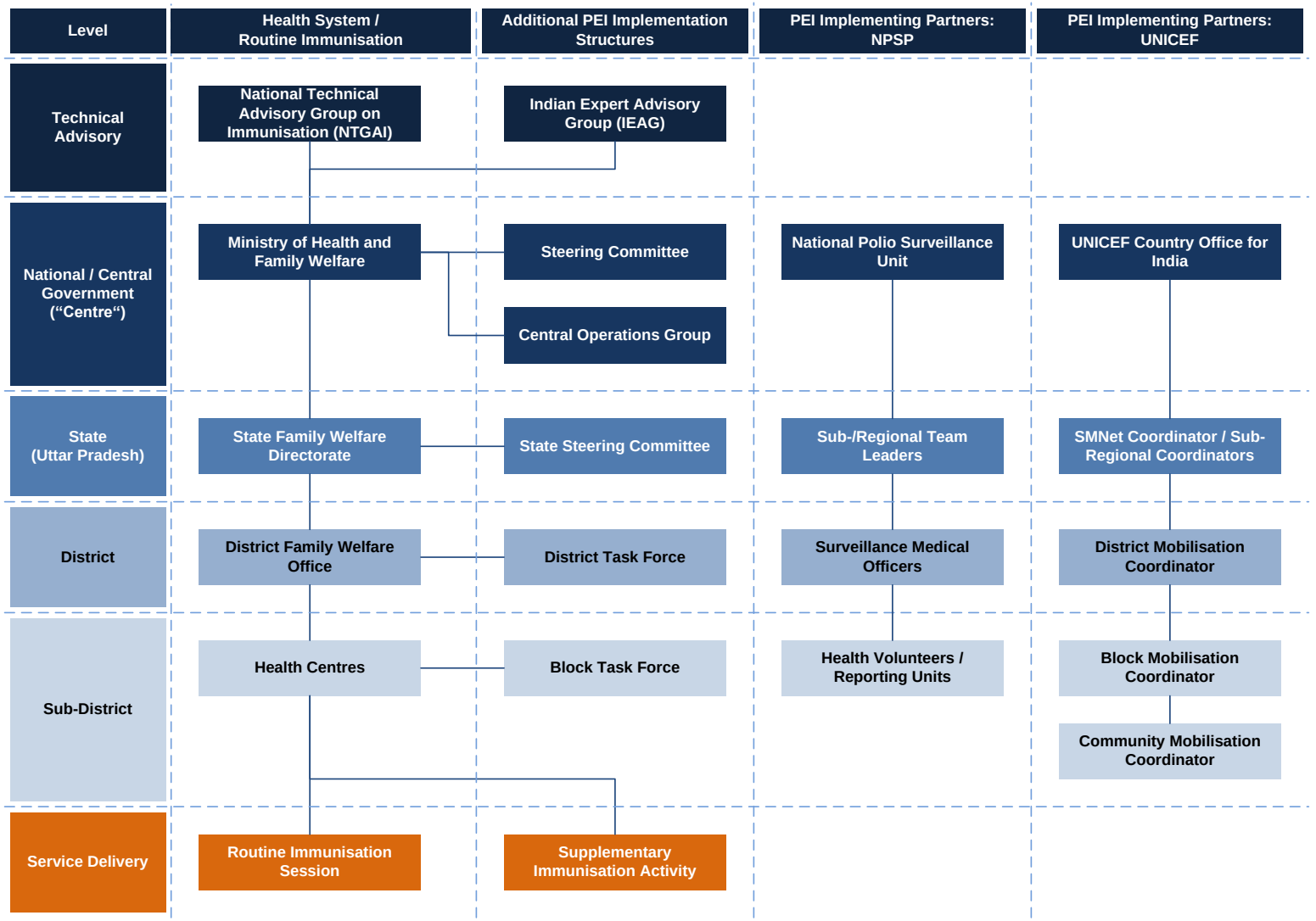
[c]Only in selected states, districts, and/or cities.

[d]UNICEF is responsible for communication activities, supported by other partners such as Rotary International.

[e]Trivalent oral polio vaccine (tOPV) is used against all poliovirus sub-types (P1, P2, and P3), with highest efficacy against P2. Monovalent OPV (mOPV) is used against P1 or P3 with a higher efficacy than tOPV. Bivalent OPV (bOPV) is used against P1 and P3 simultaneously, with higher efficacy than tOPV (but lower than individual doses of mOPV). The inactivated polio vaccine (IPV) is injectable and used against P1, P2, and P3 at higher costs but with lower risk of adverse side effects such as vaccine-associated paralytic poliomyelitis and circulating vaccine-derived poliovirus.

[f]Exception: Tetanus toxoid (TT) vaccines (administered to pregnant women and to children of 10 and 16 years of age).

Figure 1. Simplified Administrative and Implementation Structures of Routine Immunisation and Polio Eradication in India.



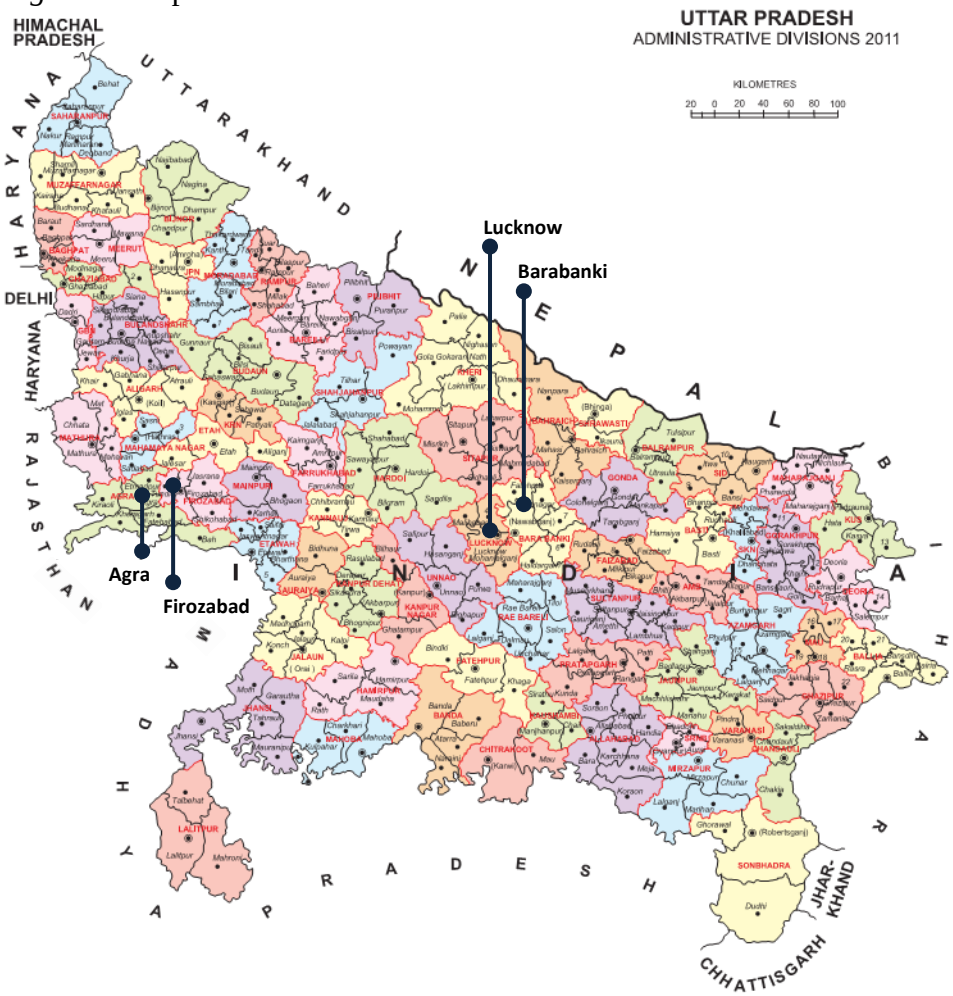
Source: Own illustration, based on Department of Administrative Reforms & Public Grievances (n.d.), NPSP (2006, 2011), UNICEF (2011), WHO (2011e).
Notes. Simplified illustration. State and lower levels specific for Uttar Pradesh. NPSP is National Polio Surveillance Project, UNICEF is the United Nations Children's Fund.

In short, although differences between the PEI and UIP exist, the programmes are by no means detached from each other. Instead, interfaces exist between them due to partial overlap in areas such as administrative and implementation structures, budgeting processes, and vaccine delivery logistics. To examine the extent to which the PEI strengthens routine immunisation as stipulated in its constituent documents, this paper applies the policy implementation framework to global health interventions as they are guided by policies to be implemented in an existing country health system. This framework is a theorisation of the policy process drawn from the field of policy analysis. Important elements for the purpose of this analysis are (a) the divergence between formulated and implemented policy and (b) the nature of the policy implementation process with agency, structures, and power being important features. This means that, in the current context, health interventions are understood as embedded in the policy process. Interventions guided by policies entail internal contradictions in an existing healthcare system, which need to be mediated by lower-tier bureaucrats. Whether the implementation of the global health intervention is successful depends on institutional mechanisms to align policy and implementation, *and* on the autonomy enjoyed by lower-tier decision makers. Seen from this perspective, what is important is not only the outcome of the health intervention, but also *what explains* this outcome.

To investigate processes and outcomes of policy implementation in global health interventions, this paper reports the findings from a set of qualitative and quantitative methods. Fieldwork for this research took place between August 1 and September 15, 2011, in Uttar Pradesh and Delhi (Figure 2). As the primary means to inform whether the PEI strengthens routine immunisation, 47 semi-structured interviews with 67 informants were conducted along the implementation chain (some interviews included more than one respondent; Figure 3). In addition, two focus group discussions with frontline implementers (nurses and doctors) were conducted, one each in Lucknow and Barabanki. In order to understand context and work practices in health service delivery, the implementation practice in both polio eradication and routine immunisation was explored through non-participant observation. Finally, a review of documentary sources was conducted (Table 3) in order to triangulate and contextualise the information gathered from semi-structured interviews and focus group discussions, to understand the health system context in which the policy implementation takes place, and to complement the data set for the quantitative analysis. The quantitative analysis examines the outcomes of the PEI's routine immunisation strengthening policy on a larger scale through logistic regression of household data from the Indian District Level Household and Facility Survey 2002-4 and 2007-8 (Table 2).

The remainder of this paper is structured as follows: Section 2 presents qualitative findings on the congruence of policy formulation and its implementation. As an imbalance between polio eradication and routine immunisation strengthening is detected, Section 3 explores quantitatively whether this has repercussions on routine immunisation attainment in Uttar Pradesh. Section 4 concludes that one explanation for the observed incongruence between formulated and implemented policy is the primacy of scientific knowledge in healthcare in India, which empowers the National Polio Surveillance Project as principal implementation partner yet with a mandate that focuses primarily on polio eradication.

Figure 2. Map of Field Sites in Uttar Pradesh.



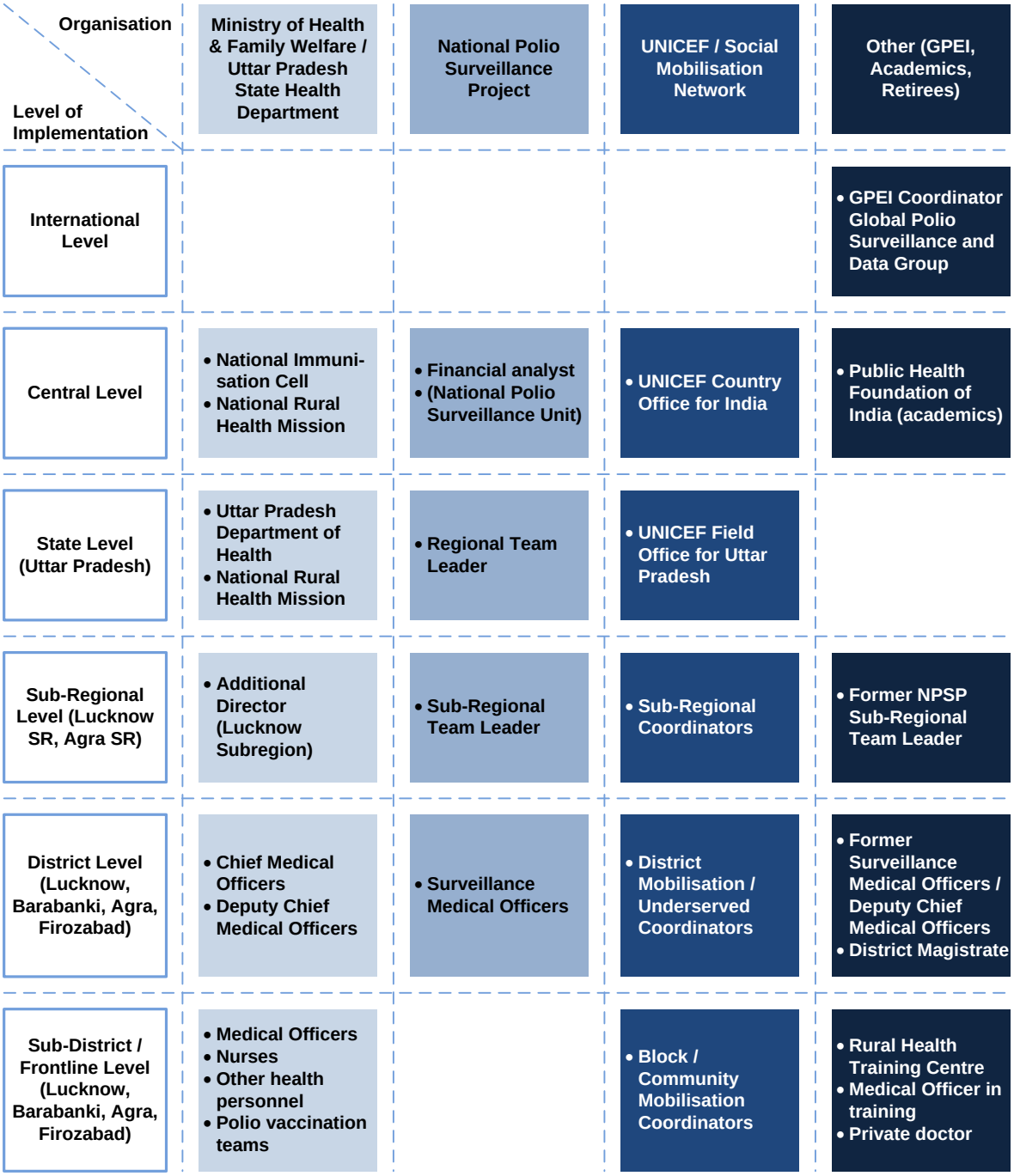
Source: Adapted from GoI (2011a:29).

Table 2. Summary of District-Level Household and Facility Survey, Rounds 2 and 3.

	DLHS II (2002-2004)	DLHS III (2007-2008)
Sampling	Multi-stage, stratified systematic sampling with population weights (representative)	
Geographical Scope	Nationwide	
Sample Size	620,107 households 507,622 currently married women 15-44 40,795 health facilities	720,320 households 634,944 ever married women 15-49[a] 31,445 health facilities
Immunisation Indicators (All India Average)	Children 12-23 months (*n* = 62,505): BCG: 75.0% DPT 3: 58.2% Measles: 56.0% Polio 3: 57.2% Full immunisation: 45.8%	Children 12-23 months (*n* = 65,628): BCG: 86.7% (86.7%) DPT 3: 63.4% (63.5%) Measles: 69.1% (69.5%) Polio 3: 65.6% (66.0%) Full immunisation: 53.5% (54.0%) (parentheses adjusted for currently married mothers 15-44, *n* = 64,702)
Data Quality	Sample response rates: Households: 98.9% Currently-married women: 86.8% Vaccinations recorded on vaccination card (12-23 months): 31.0%	Sample response rates: Households: 94.0% Ever-married women: 89.0% Vaccinations recorded on vaccination card (12-23 months): 42.9%

Source: Own elaboration, based on IIPS (2005, 2006, 2010a).
[a]Pooled data set has been adjusted to children of currently married mothers aged 15 to 44 years.

Figure 3. Overview of Semi-Structured Interviews.



Source: Own illustration.

Notes. Entries in parentheses indicate informal conversations that do not count towards the sampled interviews. NPSP is not active on the sub-district level. GPEI is Global Polio Eradication Initiative, NPSP is National Polio Surveillance Project, SR is sub-region, UNICEF is the United Nations Children's Fund.

Table 3. Overview of Documentary Sources and Their Use.

Document Type	Use of Information and Data			Sources
	Health System Context	Research Question 1	Research Question 2	
International Policy Regime	• Contextualisation of programme policies			• WHA • GPEI
National and State Health Policies	• Health system status • Contextualisation of programme policies	• Programme governance		• National Health Committees • Planning Commission • GoI • MoHFW
Programme Policy Documents	• Comparison of programme features • Programme strategies	• Programme governance	• Polio round exposure variable	• India Expert Advisory Group • MoHFW • NPSP • UNICEF
Policy Evaluations	• Comparison of programme features	• Triangulation of qualitative findings	• Triangulation of quantitative findings	• WHO • MoHFW • NRHM • Independent Evaluators
Other Policy Documents (Standards, Annual Reports, Health Data)	• Health system status • Programme structures	• Triangulation of qualitative findings		• MoHFW
Policy Implementation Plans, Handbooks, and Guidelines	• Health system status • Programme structures	• Triangulation of qualitative findings • Programme governance • Financial and human resources • Vaccine logistics		• GoI • MoHFW • NRHM • NPSP • UNICEF
Planning, Monitoring and Review Formats		• Implementation support in planning and monitoring • Monitoring formats and reporting requirements		• UP Department of Health • NPSP • UNICEF
Briefing Material	• Implementation support structures	• Implementation partner support		• UNICEF
Implementation Data		• Triangulation of qualitative findings • Implementation of RI strengthening policy	• Polio round exposure variable	• UP Department of Health • NPSP • UNICEF

Source: Own elaboration.

Notes. GoI is Government of India, GPEI is Global Polio Eradication Initiative, MoHFW is Ministry of Health and Family Welfare, NPSP is National Polio Surveillance Project, NRHM is National Rural Health Mission, UP is Uttar Pradesh, UNICEF is the United Nations Children's Fund, WHA is World Health Assembly.

2 Qualitatively Examining the Congruence Between Formulated and Implemented Programme Policy

The following section reports qualitative findings on the implementation of the PEI's routine immunisation strengthening policy. The first sub-section is concerned with the translation of strategic decisions of the PEI's policy-making body into operational guidelines for the implementers. The following sub-sections explore how the ensuing ambiguity manifests itself with respect to financial resource allocation and vaccine delivery logistics. These areas highlight the implicit prioritisation of polio eradication vis-à-vis routine immunisation strengthening within the PEI.

2.1 Strategic Decision-Making

Although the eradication of polio is continuously re-affirmed by policy makers and is stipulated as a national health priority in policy documents such as the National Health Policy 2002 (CCHFW, 2009:7, 40; MoHFW, 2002b: Box IV), there exists no formalised national polio policy. The PEI programme policy is instead made in the form of strategic programme decisions by the India Expert Advisory Group (IEAG) as the *de facto* decision-making authority. These programme policies indeed emphasise the strengthening of routine immunisation and its operations. A review of the minutes of the IEAG meetings over the last ten years shows that this strategic link has developed over time as the PEI intensified and matured. For example, the IEAG only irregularly mentioned routine immunisation in its recommendations before 2002 (six years after programme inception), after which RI became a regular category of analysis and recommendation (IEAG, 2001:3, 2002:6). Within the IEAG recommendations, the concern regarding routine immunisation operations is not confined to the *polio* vaccine (OPV). For instance, the IEAG emphasises the provision of DPT vaccinations and recommends combining BCG vaccines with OPV birth doses (IEAG, 2003a:6, 2003b:6).[2] In other words, the strategic decisions within the PEI demonstrate a concern for polio immunisation *and all other vaccines* in the UIP.

The adoption of these policies requires translation into operational guidelines, which introduces ambiguity into the interpretation of "routine immunisation strengthening. The guidelines of the PEI implementing partners illustrate this: the *Field Guide* of the National Polio Surveillance Project (NPSP) translates routine immunisation strengthening into "achieving and maintaining high routine coverage in infants younger than 1 year with at least 3 doses of oral polio vaccine (OPV3)" (NPSP, 2005:8). Because there is no mentioning of other routine immunisation vaccines such as BCG or DPT, this represents a rather narrow focus on the polio-component of routine immunisation. Other guidelines, for example by the UNICEF Field Office in Lucknow, interpret routine immunisation strengthening in broader terms. In the so-called convergence strategy in the context of the 107 Block Plan (a recent initiative that intends to integrate polio eradication, routine immunisation, nutrition, sanitation, hygiene, and education), UNICEF's guidelines emphasise, "Ensuring all parents of under five children in the high risk blocks know about the importance of RI [routine immunisation] and the RI schedule" (UNICEF, 2010:2).[3] Interviews with officers from the Ministry of Health and Family Welfare (MoHFW) as well as from the implementing partners UNICEF and NPSP echo such divisions. These ambiguous interpretations

[2]The BCG (Bacillus Calmette-Guérin) vaccine is used against tuberculosis; DPT against diphtheria, pertussis, and tetanus.

[3]Although the NPSP is adapting to this broader perspective, it remains largely confined to the 107 blocks (NRHM, 2010:432).

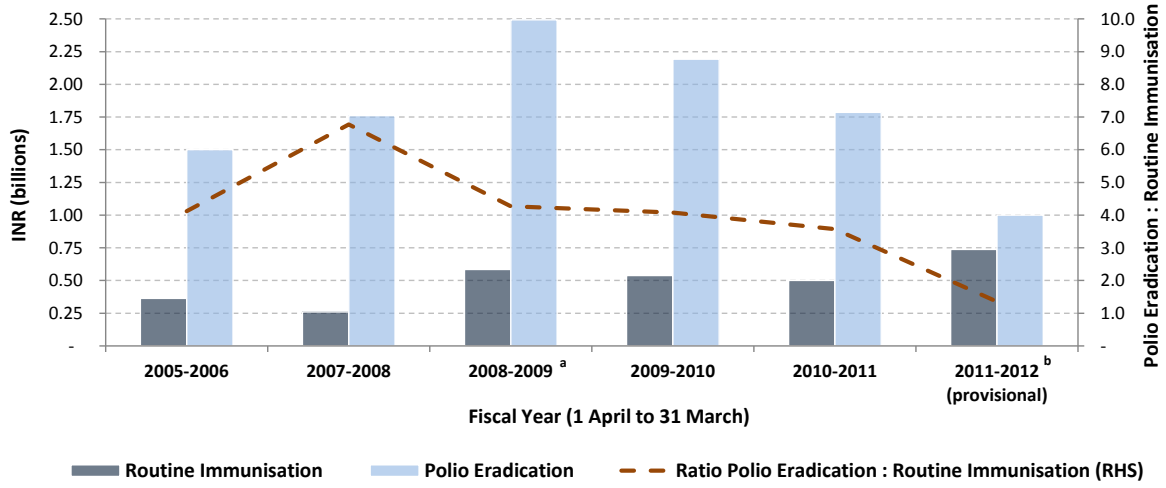
as to how routine immunisation ought to be strengthened create space for a mismatch between policy and implementation.

2.2 Budgeting and Financial Resource Allocation

Trends in the relative and absolute allocation of financial resources between polio eradication and routine immunisation are likely linked to the ambiguity in the operational guidelines. Polio eradication endowments disproportionately exceed routine immunisation, and it appears that routine immunisation funding falls short of levels required to deliver services sufficiently.

The annual national budgets for polio eradication and routine immunisation (both including vaccine and operating costs) are GBP 150 million and GBP 65 million, respectively (MoHFW, 2011a:60). In addition, external funding for the PEI implementation support is in the magnitude GBP 12 million for the NPSP and GBP 6 million for UNICEF's SMNet (Field notes and Jafari, 2008:20). Figure 4 displays the financial allocations to routine immunisation and polio eradication specifically for Uttar Pradesh. These data show that polio eradication funding has exceeded routine immunisation in recent years three- to seven-fold. In other words, whereas approximately GBP 1.00 to 1.40 per child per year are spent in Uttar Pradesh on polio eradication campaigns, GBP 0.15 to 0.30 per child are used for vaccinating against the six childhood diseases (including polio) in the routine immunisation programme. Only in the most recent funding proposal is this ratio lowered to 1.35, owing to increased spending on routine immunisation and reduced projected expenditures for polio eradication.

Figure 4. Financial Resource Allocation, Uttar Pradesh, 2005-06 to 2011-12.



Source: Own illustration, based on NRHM (2008:2, 2011c, 2011b:12-13, 355, 328).
Notes. Approved partial budgets of the National Rural Health Mission in Uttar Pradesh. No values for routine immunisation available for 2006-2007 (polio eradication accounted for INR 1.6 billion). RHS is right hand side.
[a]Routine immunisation: proposed to Government of India for approval.
[b]Proposed to Government of India for approval.

While disagreements arise among interview respondents as to whether the relative allocation of funds between the two programmes is justified, also *absolute* funding levels indicate that polio eradication is well endowed in contrast to routine immunisation. There appears to be a consensus among the informants that the Polio

Eradication Initiative does not suffer from financial shortages and that any funding gaps are met through external donor support. In contrast, the perceptions about routine immunisation financing levels are more mixed. For example, the Chief Medical Officer of Lucknow district states that, "For polio, we often surrender unused funds of a couple of thousand rupees. For routine immunisation, this is not the case. The funds are very little, so there is nothing left." However, especially respondents from the lowest implementation levels (e.g., nurses) were more optimistic about the sufficiency of routine immunisation funding.

Overall, the Polio Eradication Initiative enjoys a much better financial position than routine immunisation. Respondents' views on the balance of such allocations are mixed, but especially from higher levels of the implementation chain, opinions emerge that financial resource allocation for polio is disproportionately high. This resonates with Laxminarayan and Ganguly (2011:1100-1101), who recently claimed that the goal of universal immunisation under the UIP in India is unattainable at current levels of financing. The implicit prioritisation of polio therefore raises doubts about the coherence with the policy of supporting routine immunisation through the PEI's *supplementary* immunisation activities.

2.3 Vaccine Delivery Logistics

Cold chain management and vaccine delivery (i.e., delivery from the point of supply to the point of application) are two areas of vaccine delivery logistics performance that are often claimed to benefit from polio eradication. However, in accordance with the preceding sub-section, performance levels across the two programmes differ and the PEI may even be to the detriment of routine immunisation operations in some occasions.

Especially among central-level actors and the implementation partners, routine immunisation cold chain management is thought to benefit from the PEI immunisation activities. This is because of the overlap in their vaccine strategies with respect to the oral polio vaccine (OPV), and because the PEI mass immunisation campaigns require extensive cooling capacity to maintain vaccine efficacy that could be utilised for routine immunisation delivery. Nevertheless, the positive effects seem to be selective and occasionally even negative. One example comes from an informant who served as NPSP Surveillance Medical Officer and as Deputy Chief Medical Officer in Uttar Pradesh. He argues, "The vaccine supply for RI [routine immunisation] is not stable. The cold chain is not used for RI, the freezers are only used for polio ice packs." A recent UNICEF assessment lends support to such claims, stressing the insufficiency of the available cold chain infrastructure and management capacity for the Universal Immunisation Programme (UNICEF, 2008:21-31, 92-96).

Furthermore, differences in the performance levels of vaccine delivery logistics indicate that the UIP does not benefit as much from the PEI as its routine immunisation strengthening policy suggests. Contrary to the PEI, routine immunisation seems to be impaired by problems in vaccine delivery logistics. Especially nurses, responsible for delivering vaccines in the PEI and UIP, provide support for this claim. Their perception of relatively weak logistics in the UIP is corroborated by routine immunisation monitoring data made available by UNICEF. For example, in Barabanki and Lucknow, 10% and 13% of the scheduled RI sessions between January and November 2011 were not held, logistics problems being the predominant underlying reason (fieldwork data, provided by UNICEF; similar trends also exist for other districts of Uttar Pradesh). In contrast, only a portion of 2.0% to 2.9% of all children in Uttar Pradesh did not receive

the oral polio vaccine during polio immunisation rounds between May 2009 and June 2011 (Lal, 2011:12). Albeit this indicator is slightly different from the number of sessions held, vaccine logistics need to be fully functional in order to achieve such a high coverage. This indicates considerably higher vaccine delivery logistics performance in the PEI and suggests that the spillovers to routine immunisation are limited and short of the PEI's potential.

2.4 Summary

The Polio Eradication Initiative has been widely considered a remarkable success (e.g., Grassly et al., 2009:20), leading to little doubt on positive spillovers to routine immunisation. Also the strategic decisions made by the Indian Expert Advisory Group suggest that the "strengthening of routine immunisation" is a strategic objective as stipulated in the constituent documents of the Global Polio Eradication Initiative. Yet the interpretation of these strategic decisions by programme actors yields ambiguity that potentially contradicts the implementation of the policy. The analysis of financial resource allocation suggested that the ambiguity resolves in a disproportionate financial support for polio eradication, although the informants disagree whether this is justified. Similar trends can be observed in terms of vaccine delivery logistics, where a lower performance of cold chain management and vaccine delivery in routine immunisation indicate that the PEI policy to strengthen routine immunisation is at best selective. The following section explores whether the mismatch policy implementation processes have a discernible impact on the attainment of routine immunisation.

3 Quantitatively Assessing the Impact of Polio Eradication on Routine Immunisation Uptake

This section explores whether the alleged divergence between the formulated and implemented routine immunisation strengthening policy of the PEI has a discernible impact on routine immunisation outcomes in Uttar Pradesh when controlling for other determinants of full immunisation such as child age, maternal education, or household wealth (see Table 4). The outcome in question is *full* immunisation against all routinely administered pathogens according to the Indian national immunisation schedule (specifically full immunisation with BCG, DPT, and Measles vaccine; thus neither merely the *polio* vaccine nor *partial* immunisation).

Table 4. Main Determinants of Full Immunisation and Hypothesised Impact.

Determinant	Hypothesised Influence on Full Immunisation (+ / –)	Sources
Supply: Health System		
Political and Institutional Context	Supportive supervision in place (+)	Babu et al. (2011b) Gauri and Khaleghian (2002)
Health Infrastructure	Proximity to health facilities (+)	Datar et al. (2007) Phukan et al. (2009)
Availability of Health Personnel	High number of nurses per 1,000 population (+)	Anand and Bärnighausen (2007)
Vaccine Supply	All vaccines are available (+)	Interview 12
Demand: Community Level		
Adverse Effects Following Immunisation	Incidence of vaccine-associated paralytic poliomyelitis (–)	Interview 12
Epidemiological Context of Household	Outbreaks of vaccine-preventable diseases (+)	Nichter (1995) Interview 9
Demand: Household Level		
Household Standard of Living	High wealth or asset index (+)	De and Bhattacharya (2002) Nath et al. (2007)
Religion	Household head is Muslim (–)	De and Bhattacharya (2002) Jeffery and Jeffery (2011) Nath et al. (2007) Nichter (1995) Pande (2003)
Demand: Maternal (and Paternal) Level		
Education of Parents	Years of schooling of mother (+)	De and Bhattacharya (2002) Gauri and Khaleghian (2002) Pande (2003)
Mother's Awareness of Immunisation	Mother received ante-natal care (+)	De and Bhattacharya (2002) Nichter (1995)
Demand: Child Level		
Birth Order	High birth order (child has higher number of older siblings) (–)	Pande (2003)
Sex of Child	Child is girl (–)	Nichter (1995) Pande (2003)

Source: Own elaboration.
Notes. Only indicative. (+) / (–) denote positive / negative hypothesised relationship of example to likelihood of child to be fully immunised.

3.1 Hypotheses

According to the interviews conducted with programme decision-makers and implementers, the impact of the Polio Eradication Initiative on routine immunisation is ambiguous. On the one hand, the PEI may *raise* routine immunisation uptake as the repeated contact between vaccination teams and households stimulates demand for routine immunisation. On the other hand, the repeated household visits to vaccinate against polio may also result

in "immunisation fatigue" and curtail demand. In addition, the occupation of health workers with up to twelve 6- to 11-day polio immunisation rounds per year may compromise essential healthcare services including routine immunisation. This argument would especially apply to Uttar Pradesh as a state with a high frequency of polio eradication rounds. Because of the previously established mismatch between the formulated and implemented PEI policy to strengthen routine immunisation, the first hypothesis follows the second line of argument:

H1: A high intensity of polio eradication activities has a negative effect on children's probability to receive full immunisation.

Proponents of the polio programme do not necessarily contest the potentially disruptive capacity of polio eradication for *single* routine immunisation sessions. Rather, they argue that missed vaccinations can be easily followed up during subsequent routine immunisation sessions. Therefore, everything else being equal, the second hypothesis poses the following:

H2: The routine immunisation uptake of older children is less affected by intense polio eradication activities because they can catch up on missed routine vaccinations.

3.2 Overview of the Statistical Model

The logistic regression model in Equation (1) was estimated to examine these hypotheses (see Table 5 for a summary of the variables). The model assesses the association between the immunisation status of a child and the number of polio immunisation rounds (i.e., 6- to 11-day mass campaigns within sub-/national polio immunisation days and large-scale mop-up campaigns) to which it has been exposed, controlling for other determinants of full immunisation.

$$\text{logit}[P(y = 1)] = \alpha + \beta_p pol + \beta_c CHI + \beta_m MOT + \beta_h HH + \beta_i INF + \beta_x INT + \beta_o CON$$

Table 5. Variables Included in Full Logistic Regression Model.

Variable / Vector	Variable / Vector Description	Included Variables
Dependent Variable		
P(y = 1)	Child's probability to attain full vaccination status, ages 10 to 30 month, Uttar Pradesh and Bihar	• Vaccination status ([1] if all vaccines of immunisation schedule have been received, see Table 5.4 for the four indices used)
Independent Variables		
pol	Polio round exposure	• Number of polio rounds to which the child has been exposed throughout her or his life
CHI	Child-level characteristics	• Age of child • Sex of child • Birth order
MOT	Maternal and paternal characteristics	• Level of education in years (mother, father) • Age of mother at birth • Awareness: ▪ Possession of vaccination card ▪ Received ante- and post-natal care ▪ Received advice to vaccinate child
HH	Household-level characteristics	• Household size • Standard of living index • Caste dummy • Religion dummy (other than Muslim)
INF	Health system-level characteristics	• Rural / urban location dummy • District dummy
INT	Interaction terms	• Polio round exposure x age of child (POLxAGE) • Polio round exposure x survey round (POLxSUR) • Polio round exposure x rural / urban (POLxURB)
CON	Other control variables	• Survey round dummy

Source: Own elaboration.
Notes. Vectors indicated by capitalised italics. Note further that dummy variables of "health system-level characteristics" capture effects beyond healthcare, e.g. political and other infrastructural differences.

The immunisation status as dependent variable consists of a binary index that assumes the value of 1 if full immunisation is attained. The data used for constructing this immunisation index is based on parent recall and vaccination card information (Pande, 2003:400-401). Vaccines reported in the Indian District Level Household and Facility Survey questionnaire (and included in the official Indian immunisation schedule) are BCG, OPV, DPT, hepatitis B, and measles (MoHFW, 2002a:7; 2005b:9; 2008:19, 2011b:11). The oral polio vaccine (OPV) and hepatitis B were excluded from the immunisation index used as outcome measure owing to potential endogeneity and recall biases (OPV) and low coverage (hepatitis B). Thus, the dependent variable will be based on a narrower immunisation index than what the official immunisation schedule provides (Table 6).

The independent variable of principal interest is the child's exposure to (or number of contacts with) polio immunisation rounds (*pol*). This is a child-specific

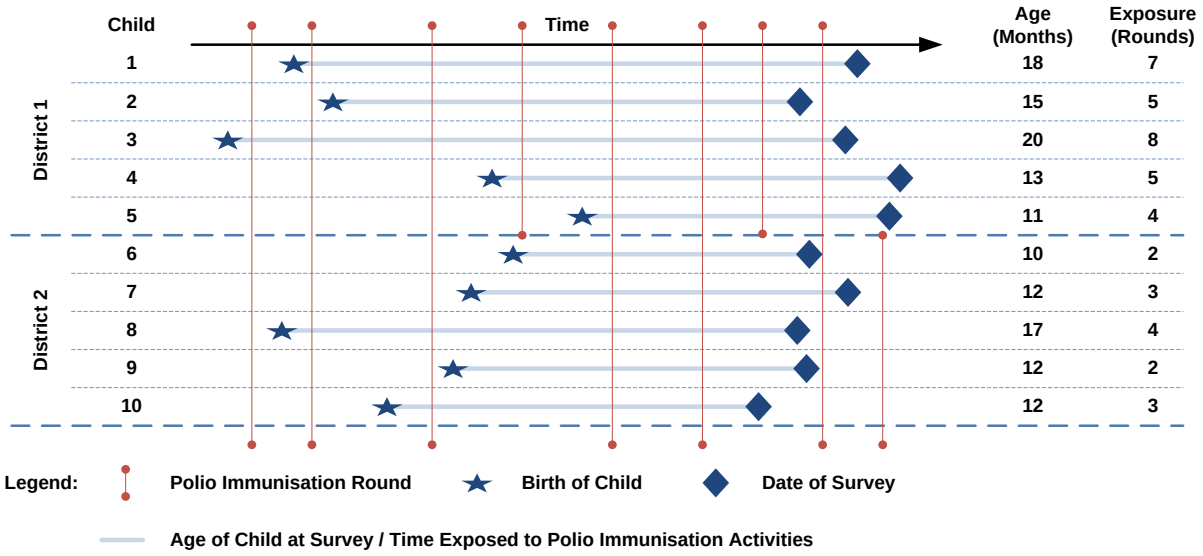
variable, indicating the number of polio immunisation rounds (large-scale mop-ups and sub-/national immunisation days) to which the child has been exposed. This exposure differs across children depending on their date of birth, the date of the survey, and the district in which they live (see Figure 6 for an illustration). A data set containing this information was constructed using publicly available sources. This was complemented by policy documents to establish historical immunisation patterns and interpolate gaps in the immunisation maps. Table 7 summarises the underlying data according to survey round.

Table 6. Immunisation Index Used as Dependent Variables.

Immunisation Index	
BCG	✓
DPT 1, 2, 3	✓
Measles	✓
Hepatitis B	
OPV 1, 2, 3	

Source: Own elaboration.
Note. Checkmark indicates that vaccine is included in index.

Figure 5. Schematic Depiction of Polio Round Exposure Variable.



Source: Own illustration.
Notes. For illustrative purposes only. Not based on actual data.

Table 7. Summary Statistics of Data Sets for Uttar Pradesh, Children Aged 10 to 30 Months.

Variable Name	Variable Description	DLHS II (2004)						DLHS III (2008)					
		N	Mean	Median	Min	Max	Std. Dev.	*N*	Mean	Median	Min	Max	Std. Dev.
Dependent Variables: Immunisation Indices													
i_index1_dbm	Imm. Index (BCG, DPT, Mea.)	17,530	0.27	0	0	1	0.45	18,022	0.32	0	0	1	0.47
i_index2_dbmh	Alternative Index (BCG, DPT, Mea., HepB)	17,526	0.06	0	0	1	0.23	17,416	0.07	0	0	1	0.25
i_index3_dbmp	Alt. Index (BCG, DPT, Mea., OPV)	17,436	0.27	0	0	1	0.44	16,370	0.33	0	0	1	0.47
i_index4_dbmph	Alt. Index (BCG, DPT, Mea., OPV, HepB)	17,432	0.05	0	0	1	0.23	15,849	0.07	0	0	1	0.25
Dependent Variables: Memo Items													
ch_BCG	Received one dose BCG vaccine	17,714	0.58	1	0	1	0.49	19,606	0.76	1	0	1	0.43
ch_DPT_3plus	Received three or more doses DPT vaccine	17,530	0.37	0	0	1	0.48	18,734	0.39	0	0	1	0.49
ch_HEP	Received one dose HepB vaccine	17,710	0.07	0	0	1	0.26	19,910	0.11	0	0	1	0.31
ch_MEA	Received one dose measles vaccine	17,714	0.35	0	0	1	0.48	19,083	0.49	0	0	1	0.50
ch_POL_3plus	Received three or more doses OPV	17,529	0.36	0	0	1	0.48	17,267	0.44	0	0	1	0.50
Independent Variables: Exposure to Polio Programme													
pol	Child's exposure to no. of polio rounds	17,777	7.81	7	2	15	3.17	20,733	14.69	14	7	24	3.88
Independent Variables: Child Level													
ch_index	Birth order of child	17,778	3.38	3	1	16	2.17	20,733	1.18	1	1	4	0.40
ch_sex	Sex of child (1 = girl)	17,778	0.48	0	0	1	0.50	20,733	0.48	0	0	1	0.50
ch_age	Age in months	17,778	20.14	20	10	30	6.01	20,733	20.11	20	10	30	6.06
Independent Variables: Maternal (and Paternal) Level													
husb_school	Husband's years of schooling	12,196	9.35	9	0	23	3.48	20,627	6.36	8	0	22	5.02
m_age_at_birth	Age of mother in years at birth of child	17,778	24.73	23.8	13.1	43.2	5.61	20,733	24.80	23.9	12.6	43.2	5.43
m_school[a]	Mother's years of schooling[a]	17,778	2.86	0	0	22	4.54	20,733	3.05	0	0	19	4.48
m_anc	Received ante-natal care	17,315	0.73	1	0	1	0.44	20,183	0.64	1	0	1	0.48
m_pnc	Received post-natal care or assisted delivery	17,324	0.37	0	0	1	0.48	20,183	0.44	0	0	1	0.50
ch_VACCadv	Advice by health staff to vaccinate child	17,697	0.29	0	0	1	0.45	20,690	0.68	1	0	1	0.47
ch_healc_seen	Has and presented vaccination card for child	17,713	0.13	0	0	1	0.34	20,732	0.26	0	0	1	0.44
ch_healc_notseen	Has vaccination card for child (not presented)	17,713	0.26	0	0	1	0.44	20,732	0.30	0	0	1	0.46

Variable Name	Variable Description	DLHS II (2002-2004)						DLHS III (2007-2008)					
		N	Mean	Median	Min	Max	Std. Dev.	*N*	Mean	Median	Min	Max	Std. Dev.
Independent Variables: Household Level													
hh_size	Household size	17,778	8.41	7	2	40	4.16	20,733	7.79	7	2	44	3.73
hh_SLI_quint	Household standard of living (quintiles)	17,778	2.65	2	1	5	1.32	20,733	2.68	2	1	5	1.22
hh_rel_notmuslim	Religion of household head: other than Muslim	17,778	0.81	1	0	1	0.40	20,732	0.81	1	0	1	0.39
hh_caste_schcaste	Caste group: Scheduled caste	17,579	0.23	0	0	1	0.42	20,675	0.22	0	0	1	0.41
hh_caste_schtribe	Caste group: Scheduled tribe	17,579	0.01	0	0	1	0.11	20,675	0.01	0	0	1	0.12
hh_caste_OBC	Caste Group: Other backward class	17,579	0.53	1	0	1	0.50	20,675	0.57	1	0	1	0.50
hh_caste_general	Caste Group: General class	17,579	0.23	0	0	1	0.42	20,675	0.20	0	0	1	0.40
Independent Variables: Health System Level													
hh_rur_urb	Rural / urban dummy (1 = urban)	17,778	0.26	0	0	1	0.44	20,733	0.15	0	0	1	0.36
district_dummy	District dummy (one for each district)	17,778						20,733					
Independent Variables: Other Control Variables													
survey_dummy	Survey dummy (1 = DLHS III)	17,778	0					20,733	1				
Independent Variables: Memo Items													
date_CMC	Date of survey in century month code	17,778	1240.8	1249	1225	1259	11.57	20,733	1298.1	1298	1285	1301	1.34
	(date in years)		2003.4	2004.1	2002.1	2004.9	1.0		2008.2	2008.2	2007.1	2008.4	0.1
ch_last	Last (0) or next-to-last (1) child	17,778	0.13	0	0	1	0.34	20,733	0.14	0	0	1	0.34
ch_dob_cmc	Date of birth of child in century month code	17,778	1220.7	1220	1196	1247	12.84	20,733	1278.6	1279	1259	1290	6.21
	(date in years)		2001.7	2001.7	1999.7	2003.9	1.1		2006.5	2006.6	2004.9	2007.5	0.5
m_age	Age of mother at survey in years	17,778	26.41	26	15	44	5.63	20,733	26.48	26	15	44	5.45

Source: Own elaboration.

Notes. DLHS III sample adjusted to children aged 10 to 30 months of currently married mothers aged 15 to 45 years. Due to limited historical data on programme intensity, child age in the sample had to be capped at 30 months. Health system level excluded because of data quality concerns. A date consisting of a year and a month is converted into the century month code by subtracting 1900 from the year and multiplying it with 12, added by the month (this corresponds to the number of months passed since the year 1900). BCG is Bacillus Calmette-Guérin vaccine, DPT is diphtheria, pertussis, and tetanus vaccine, Mea. is measles vaccine, OPV is oral polio vaccine, HepB is hepatitis B vaccine.

[a]Gatekeeper variable included: 0 years is equivalent to mother being illiterate.

3.3 Results

This sub-section reports the results of the quantitative analysis. As shorthand, a result will be referred to as "significant" if the significance level of an estimator's coefficient surpasses the five per cent level (i.e., its *p*-value is below 0.05). The model goodness-of-fit was assessed through the Pseudo-R^2 and the Akaike Information Criterion.

3.3.1 Hypothesis 1: Link Between Polio Round Exposure and Immunisation Uptake

The first hypothesis suggested that a higher exposure to polio eradication activities lowers children's chances to receive full immunisation. Table 8 presents the results for the regression model using Immunisation Index 1 (comprising BCG, DPT, and measles vaccines; excluding OPV and HepB), This table includes the full model (Model 1) and the "restricted" model (Model 2; a reduced or nested model providing the best compromise between number of independent variables, explained model variance, and sample size). The main insight from this table is a negative association between the exposure to polio rounds and a child's odds to be fully immunised.

The main variable of interest (the coefficient of the polio round exposure variable) is negative and significant at the 0.1 per cent level. The coefficient of -0.056 corresponds to a *decrease* of 5.45% in the odds of a child to be fully immunised *when exposed to an additional polio round*, in the presence of the given control variables.[4] For example, increasing the exposure from 14 to 15 polio rounds would reduce the probability of full immunisation from 12.2% to 11.6%, given a hypothetical male child at the age of 20 months in the district of Bareilly, and who represents median sample characteristics of the DLHS III (see summary statistics Table 7). On average across the sample, an additional polio round is associated with a reduction of 0.83 percentage points in the expected probability of attaining full immunisation (owing to constant change in the odd of full immunisation, the response in terms of expected probability is non-linear across the sample; thus the deviation from the preceding example).

Therefore, Hypothesis 1 cannot be rejected because a high exposure to polio immunisation rounds is linked to a lower attainment of full immunisation. It appears that the execution of polio immunisation rounds detracts from the service delivery capacity in routine immunisation (also adverse demand-side effects such as "immunisation fatigue" may be at work). In terms of the research question, this suggests that the PEI has a negative impact on the uptake of other childhood vaccines in Uttar Pradesh.[5]

[4] The change in the odds is calculated from the coefficient as follows: $1 - e^{1*(-0.056)} = 1 - 0.9455 = 0.0545$ (Hilbe, 2009:76). Note that the odds of an event with a probability of success p are $\frac{p}{1-p}$.

[5] The terminology implies a causal relationship. Appendix D provides indication that causality runs from polio round exposure to routine immunisation performance.

Table 8. Full and Restricted Regression Model.

Variable Name	Variable Description	(1) Full Model	(2) Restricted Model
pol	Child's exposure to polio rounds	-0.056*** (0.010)	-0.056*** (0.009)
ch_index	Birth order of child	-0.045** (0.014)	
ch_sex	Sex of child (1 = girl)	-0.123*** (0.030)	-0.139*** (0.028)
ch_age	Age in months	0.076*** (0.006)	0.075*** (0.005)
husb_school	Husband's years of school-ing	0.032*** (0.004)	
m_age_at_birth	Age of mother in years at birth of child	0.013*** (0.003)	0.011*** (0.003)
m_school	Mother's years of school-ing	0.064*** (0.004)	0.079*** (0.004)
m_anc	Mother received ante-natal care	0.753*** (0.041)	0.805*** (0.038)
m_pnc	Mother received post-natal care or assisted delivery	0.181*** (0.033)	0.183*** (0.031)
ch_VACCadv	Advice by health staff to vaccinate child	0.679*** (0.033)	0.748*** (0.031)
ch_healtc_seen	Has and presented vac-cination card for child	1.875*** (0.040)	1.877*** (0.038)
ch_healtc_notseen	Has vaccination card for child (not presented)	1.058*** (0.036)	1.121*** (0.034)
hh_size	Household size	0.001 (0.004)	
hh_SLI_quint	Household standard of living (quintiles)	0.103*** (0.016)	0.145*** (0.014)
hh_rel_notmuslim	Religion of household head: other than Muslim	0.336*** (0.046)	0.372*** (0.042)
hh_caste_schedtribe	Caste group: Scheduled tribe	-0.109 (0.163)	-0.062 (0.146)
hh_caste_OBC	Caste Group: Other back-ward class	-0.033 (0.039)	-0.027 (0.037)
hh_caste_general	Caste Group: General class	0.081 (0.048)	0.105* (0.046)
hh_rur_urb	Rural / urban dummy (1 = urban)	0.153*** (0.042)	0.110** (0.039)
survey_dummy	Survey dummy (1 = DLHS III)	0.130 (0.082)	0.189** (0.072)
Constant	Constant	-4.755*** (0.183)	-4.827*** (0.166)
N		28,916	34,327
Model-df		89	86
***p*-Value**		< 0.001	< 0.001
Pseudo R^2		0.237	0.248
Akaike Information Criterion		0.970	0.919

Source: Own estimation.

Notes. Coefficients reported. Standard errors in parentheses. District dummy variables not displayed. Coefficient values of different models cannot be immediately compared due to varying samples.

*p < 0.05, **p < 0.01, ***p < 0.001.

3.3.2 Hypothesis 2: Age-Specific Impact of Polio Round Exposure on Immunisation Uptake

The second hypothesis suggested that older children who missed routine immunisation in the first place are less affected by the polio programme because missed routine immunisation sessions are easily followed up. This hypothesis is tested by analysing the interaction between polio round exposure and the age of the child, as shown in Table 9 (*POLxAGE*). Model 3 shows that the sign of the polio round exposure variable is reversed compared to the initial results, while the coefficient of the multiplicative interaction term is negative and significant at the 0.1 per cent level. It is important to note that the reduced significance level of the polio round exposure coefficient from the 0.1 to the five per cent level is to be understood in connection with the significance level of the interaction term: if the *POLxAGE* interaction term is significant, both interacting variables are significant (Hilbe, 2009:197). The value of the polio round exposure variable corresponds to a 3.78% increase in the odds of full immunisation *at the age of zero months* (note that the sample contains children aged between 10 and 30 months and extrapolation beyond this range is rather dubious). Because the interaction term is negative, this initially "positive" effect of a higher polio round exposure is diminished for older children. The question then is whether, at higher ages, the sign of the polio round exposure coefficient turns negative; that is, whether the polio programme discriminates against children at a certain age. If this were the case before the age of ten months (i.e., the lower bound of the sample), all children in the sample would be at a disadvantage, with particularly negative effects accruing to older children.

Figure 6 visualises these age-specific results, including the predicted polio round exposure coefficient for Model 3 in Table 9 (bold line) and the estimates for sub-samples that only include the respective age group (i.e., 10 to 30 months; bars). The bold red line indicates the results for the full sample and suggests that the polio round exposure coefficient turns negative at an age of 12 to 13 months. The bars in Figure 6 display the results for sub-samples of each age group from 10 to 30 months, showing that the overwhelming majority of coefficients are negative (red shade) and that 7 out of 21 are significant at the five per cent level (dark red shade). In line with the results from the full sample, older children seem to have more often a significantly lower probability to receive full immunisation when exposed to an additional polio immunisation round.[6] While the polio round exposure coefficients at each age bracket are to be interpreted with caution, the results point towards a distortion of the routine immunisation programme, which surprisingly seems to discriminate against older children (i.e., it compromises their otherwise higher chances to be fully immunised).

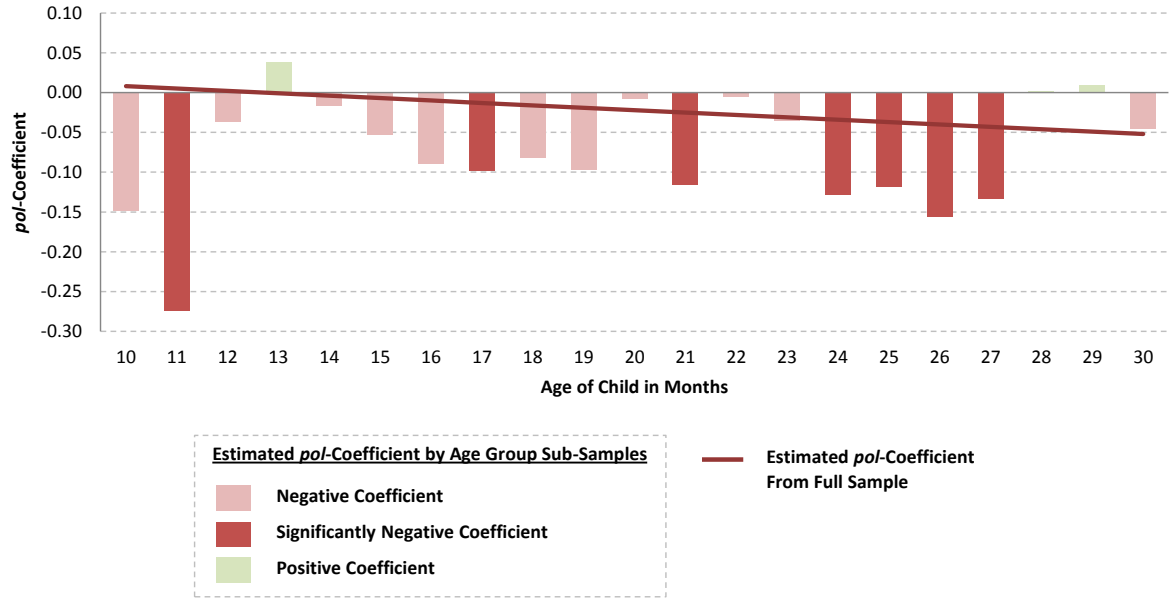
[6] Also young children at the age of 11 months appear to be particularly disadvantaged. Without attempting to over-interpret these results, this may hint at further non-linearity, which cannot be explored further within the scope of this analysis.

Table 9. Principal Results of Restricted and Interaction Models.

Variable Name	Variable Description	(2) Restricted Model	(3) POLxAGE Interaction
pol	Child's exposure to polio rounds	-0.056*** (0.009)	0.037* (0.018)
ch_age	Age in months	0.075*** (0.005)	0.102*** (0.007)
survey_dummy	Survey dummy (1 = DLHS III)	0.189** (0.072)	0.053 (0.075)
POLxAGE	Impact of child age on polio round exposure coefficient[a]		-0.003*** (0.001)
N		34,327	34,327
Model-df		87	88
***p*-Value**		< 0.001	< 0.001
Pseudo R^2		0.248	0.249
Akaike Information Criterion		0.919	0.918

Source: Own estimation.
Notes. Coefficient reported. Standard errors in parentheses. Only main results displayed.
[a]Suggested interpretation of interaction term.
*p < 0.05, **p < 0.01, ***p < 0.001.

Figure 6. Relationship Between Polio Round Exposure and Child Age, Uttar Pradesh.



Source: Own illustration, based on estimated results.
Notes. Coefficients displayed. Full sample results based on Model 3 in Table 5.7. Sub-samples estimated through Model 2 in Table 5.7 (slope based on *POLxAGE* interaction term). Bar graph representing results for sub-samples of age groups (in months). Light-shaded bars are point estimates irrespective of significance level, dark-shaded bars with significance level of at least five per cent. *POLxAGE* coefficient significant at the 0.1 per cent level. Sub-sample coefficients not immediately comparable due to different samples.

In conclusion, it emerges that young children are least affected by disruptions of routine immunisation while older children are *less likely* to receive full immunisation when they are exposed to an additional polio immunisation round.[7] This suggests that it becomes increasingly difficult for unimmunised older children to catch up on their vaccines. The existing evidence thus speaks in favour of rejecting Hypothesis H2: the immunisation status of older children is more adversely affected by a high intensity of polio eradication efforts than the vaccine uptake of younger children.

3.4 Summary

To answer the question about the impact of the PEI on the immunisation status of children in Uttar Pradesh, the quantitative analysis tested two hypotheses. Firstly, a high intensity of the Polio Eradication Initiative has a negative impact on routine immunisation uptake in Uttar Pradesh (Hypothesis 1). As it was found that the PEI adversely affects routine immunisation uptake, this hypothesis was supported. Hypothesis 2 suggested that older children are less affected by such disruptions in routine immunisation because they could catch up soon after the missed session. Yet the results show that *especially* older children are negatively affected, although less so over time. This led to reject Hypothesis 2. Interestingly, however, these results appear to be specific to the case of Uttar Pradesh. Appendix A demonstrates that the comparable case of Bihar yields contradictory and indeed rather positive outcomes of the interaction between the PEI and routine immunisation.

In sum, the statistical findings convey that the Polio Eradication Initiative detracts from routine immunisation performance in Uttar Pradesh (for robustness tests, see Appendix C). This provides further support that the PEI routine immunisation strengthening policy and its outcomes are incongruent. The outcomes for older children suggest exacerbated exclusion of already marginalised groups (at least as far as immunisation uptake is concerned).

4 Discussion and Conclusion (1285)

This paper set out to investigate the interactions between global health interventions and country health systems, using the case example of the Polio Eradication Initiative (PEI) in Uttar Pradesh, India's most populous state that continues to carry out polio immunisation activities with high intensity. Qualitative and quantitative analysis has yielded the insight that the PEI's policy to strengthen routine immunisation diverges from its actual implementation. Quantitative analysis of household-level survey data has demonstrated that the seemingly incongruent translation of policies into action is to the detriment routine immunisation attainment among children in Uttar Pradesh. But why, if guidelines are indeed ambiguous, does polio eradication dominate routine immunisation strengthening, rather than the other way round?

One explanation is the empowerment of the National Polio Surveillance Project (NPSP) in PEI programme governance through the techno-centric regime of knowledge in the Indian health policy. The implementation of the PEI (and, consequently, its routine immunisation strengthening policy) is strongly governed by "data" and "evidence," which is characteristic of the general observation of "techno-centric" approaches to health in India (Jef-

[7] Analysing a three-way interaction (*SURxPOLxAGE*) shows that the negative effect diminishes over time and an increasing group of young children may in fact benefit from the programme. However, also in the second survey round, the majority of children in the sample remains disadvantaged when exposed to a higher number of polio rounds. See Appendix B.

fery, 1996:285; John and White, 2003:173; Quadeer, 2005:91; Sathyamala and Mittal, 2006:284; Saxena, 2006:178-179). By collecting the epidemiological data that guides strategic decisions, the NPSP plays a nodal role in the governance of the PEI (MoHFW, 2005a:14, 16). Two former district-level Surveillance Medical Officers exemplify this. One argues, "They [NPSP] are […] manipulating decisions by pressuring the CMO [Chief Medical Officer] with figures," the other adds, "The NPSP is known for data, for a lot of monitoring, which is why they are powerful." These views imply a high degree of power as principal institution for data collection, maintenance, and communication.

This powerful position appears to be sustained by the high level of staff exchange between the NPSP and the Ministry of Health and Family Welfare, helping the NPSP develop a network of like-minded "graduates" in the health administration. Besides, Sheikh and Porter (2011:87) propose that, in the health sector of India, views from medical doctors are more accepted than the voices of "outsiders" without medical training. Their medical training thus seems to enable NPSP Surveillance Medical Officers to become more easily accepted by health officials than their UNICEF counterparts. Hence, with the NPSP maintaining the knowledge about the programme implementation, it is able to communicate the perceived "truth" and "relevant facts" of implementing the Polio Eradication Initiative, including its routine immunisation strengthening component.

This can be problematic as the NPSP remains focused on its principal mandate of polio eradication. The central-level Deputy Commissioner for Immunisation describes the operational constraints of the NPSP as follows: "They [the NPSP] have the mandate to work on polio eight hours a day and this is what they report. Clearly, this is their priority. You cannot have them just work on routine immunisation." The Uttar Pradesh State Immunisation Officer expresses this more critically, arguing that, "The NPSP is not doing much for [routine immunisation, …] their mandate could be expanded." This is not to suggest that the NPSP is not involved in routine immunisation. In fact, it has contributed to operational improvements through the integration of micro-planning approaches, routine immunisation monitoring and surveillance support, and through external checks against corruption in routine immunisation (GoI, 2004:15; Haldar, 2011:16-25; Pradhan, 2010; Interview with the Joint Director at the Uttar Pradesh state health department). However, because their principal mandate is polio eradication, routine immunisation support is still considered an additional task that cannot be fully pursued within the scope of the existing programme implementation approach.

Therefore, the disproportionate influence of the NPSP on PEI programme governance can potentially undermine the broad concern of the IEAG for supporting the routine immunisation programme. As the data to inform and evaluate the PEI's strategic decisions originates from the NPSP, the interpretation of what constitutes "acceptable" knowledge in the sphere of routine immunisation strengthening rests largely with a single institution. With a principal mandate that focuses on polio eradication and an operational interpretation of RI strengthening that emphasises routine *oral polio vaccine* delivery, there is indication that such a rigid evidence base entails a "pro-evidence bias" towards polio eradication rather than routine immunisation strengthening. This relates, for example, to the NPSP's inability to perceive the distinct imbalances in the fields of financial resource allocation and vaccine delivery logistics in routine immunisation, which introduces rigidities in what otherwise are positive programme governance spillovers from polio eradication to routine immunisation.

Therefore, and in line with past political economy analyses (Saxena, 2009:109), the Polio Eradication Initiative appears to disproportionately value technical inputs, thereby subordinating other regimes of knowledge and creating a natural impediment to exploring the "unknown unknowns" of programme implementation (see Pawson et al., 2011:541-543). In order to overcome these challenges, the expanded role of the NPSP in routine immunisation (despite its contributions to programme management) needs to be balanced by non-technical advisory from other programme stakeholders. The fieldwork suggests that non-technical elements may emphasise, for example, strategic programme decision-making on questions such as human resource management in routine immunisation delivery (see Haenssgen, 2012 for an analysis). That such a move would be feasible and desirable is confirmed by John (2010:A90), a member of India's National Technical Advisory Group on Immunisation (NTAGI, the technical advisory body for routine immunisation), who recently called for an inclusion of human resource issues into the technical discourse of the NTAGI. Such a shift away from the primacy of technical knowledge would require a stronger voice of non-technical stakeholders such as recipient communities and could help programme managers to revisit their optimistic assumptions on the efficacy of existing strategies in improving the operations of routine immunisation. If it is misperceived that the Polio Eradication Initiative is neutral or beneficial to routine immunisation simply because vaccines could easily be followed up, this may be a considerable obstacle to realising improvements and actually exploiting synergies between the programmes.

At the same time, the NPSP cannot be fully held responsible for the patterns observed in the data, as the case of Bihar demonstrates more encouraging results. Operational differences exist in the execution of supplementary immunisation activities for polio eradication across both states (Grassly et al., 2009:17-18). However, owing to an equally high intensity of eradication efforts, this does not seem to explain such contrasting outcomes. Instead, a number of informants highlighted the extraordinary "political commitment" of the Bihar state and health administration, commending Bihar's recent routine immunisation development as a "good-practice" example worth studying. Clearly, such a "political will" variable is impossible to capture with the data at hand, but these anecdotes underscore the potential role of state-specific factors in influencing the degree of synergy and interference between the two programmes.

The heterogeneous results across Uttar Pradesh and Bihar thus invite further examination of the state-specific determinants of programme interaction. It appears that the experience of Bihar bears valuable lessons on seizing synergies between the PEI and UIP, including the role of "political will" in achieving coherent implementation of health programme policies. Modelling such political determinants in a cross-state or cross-country study could contribute to understanding factors of success or failure of global health interventions. Besides, it is worth exploring whether the PEI affects components of the Indian health system that are *not* thought to be intrinsically synergetic with the programme. For example, antenatal care is provided by the same frontline implementers as routine immunisation (i.e., nurses), yet polio programme policies neglect this interaction. Juxtaposing such an analysis against the results for routine immunisation attainment would vastly enrich our capacity to map the positive and adverse interaction effects of large-scale mass immunisation campaigns with the health system at large. This would also help understand whether the observed synergies in Bihar extend beyond the strategic link between the Polio Eradication Initiative and routine immunisation.

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Appendix A: Replicability of Results in Bihar

The statistical analysis draws a rather negative picture regarding the impact of the Polio Eradication Initiative on the performance of routine immunisation in Uttar Pradesh, but it is not clear whether this is generalizable to other regions. Interestingly, the case of Bihar does not appear to replicate the Uttar Pradesh experience. Table A.1 compares the main results of the logistic regression model for Uttar Pradesh and Bihar (detailed results in Appendix B). Whereas most control variables have the same sign and significance level as in Uttar Pradesh (not shown), the results relating to the exposure to polio immunisation rounds are rather contradictory. For example, rather than reducing the odds of full immunisation by 5.45% in the case of Uttar Pradesh, exposure to an additional polio round *raises* the odds by 4.3% in Bihar (Models 2 and 5). This translates, on average, into a 0.83 percentage point *decrease* (Uttar Pradesh) and a 0.63 percentage point *increase* (Bihar) in the expected probability of receiving full immunisation with every additional polio immunisation round. Therefore, children in Bihar appear to have a higher probability of vaccination uptake when exposed to more polio immunisation rounds.

The case of Bihar further indicates that the magnitude of the (seemingly positive) impact of an additional polio round becomes smaller for older children (comparing Models 3 and 6). Figure A.1 illustrates the predicted polio round exposure coefficients from the full sample, and the results for sub-samples of each age group. The red line and red-framed bars are the results for Uttar Pradesh, identical to Figure 5.3 above (recall that the polio round exposure coefficient is predicted to turn negative between 12 and 13 months of age and that most significantly negative results occur among older children). For comparison, the green line and the green-framed bars in this figure present the results for Bihar. Although the results for individual age groups are less often statistically significant than the results in Uttar Pradesh (smaller sample sizes may play a role), still more than 90% of the groups have positive point estimates (green-framed bars with green shade). The comparison of the estimated results based on the full sample (i.e., the red and the green line) is even more striking. Starting from a higher level, the impact of an additional polio round on the probability of attaining full immunisation status in Bihar *remains positive for all age groups*. Although older children benefit less from an additional polio immunisation round in Bihar, they still benefit in terms of increased odds of receiving full immunisation.

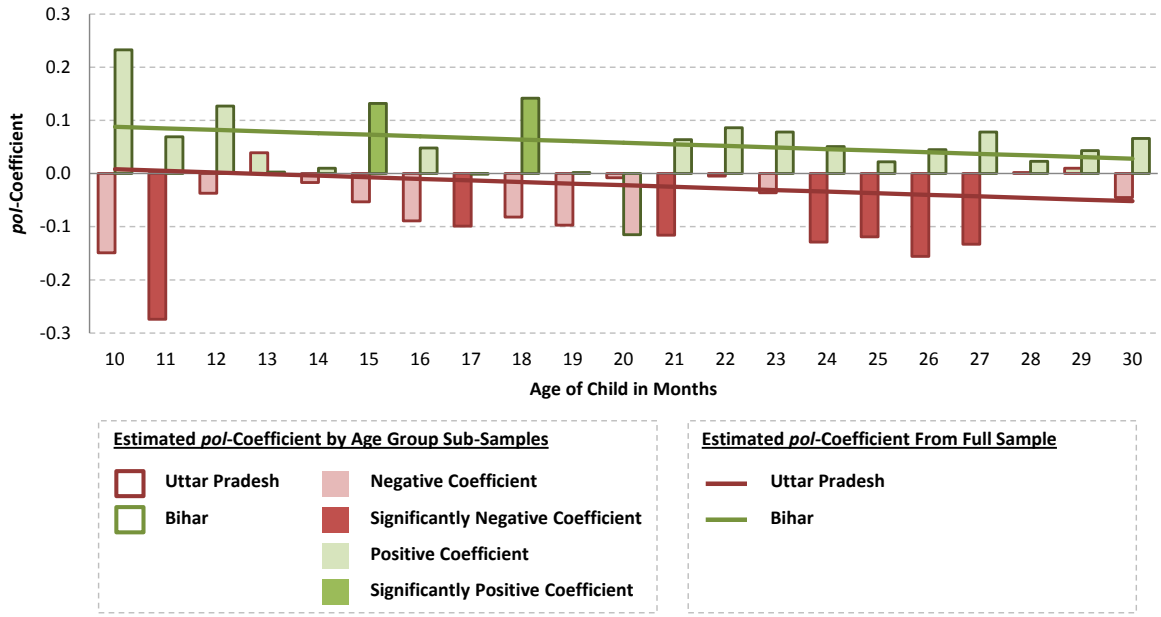
In brief, the results of the PEI's impact on routine immunisation uptake in Uttar Pradesh cannot be replicated in the state of Bihar (which also suggests that the estimation strategy is capable of revealing heterogeneous programme interaction across different regions). Therefore, the negative impact of the PEI on routine immunisation in Uttar Pradesh need not be a representative case for regions with a high intensity of polio eradication activities.

Table A.1. Comparison of Key Model Results in Uttar Pradesh and Bihar.

Variable Name	Variable Description	Uttar Pradesh			Bihar		
		(2)	(3)	(4)	(5)	(6)	(7)
		Restricted Model	POLxAGE Interaction	SURxPOLxAGE Interaction	Restricted Model	POLxAGE Interaction	SURxPOLxAGE Interaction
pol	Child's exposure to polio rounds	-0.056*** (0.009)	0.038* (0.018)	0.100*** (0.020)	0.042*** (0.01)	0.119*** (0.02)	0.176*** (0.023)
ch_age	Age in months	0.075*** (0.005)	0.102*** (0.007)	0.140*** (0.009)	0.026*** (0.006)	0.054*** (0.009)	0.082*** (0.011)
survey_dummy	Survey dummy (1 = DLHS III)	0.189** (0.071)	0.051 (0.075)	-0.396*** (0.100)	0.463*** (0.082)	0.364*** (0.085)	-0.085 (0.121)
POLxAGE	Impact of child age on polio round exposure[a]		-0.003*** (0.001)	-0.008*** (0.001)		-0.003*** (0.001)	-0.007*** (0.001)
SURxPOLxAGE	Impact of survey on POLxAGE[a]			0.002*** (0.000)			0.002*** (0.000)
N		34,327	34,327	34,327	20,525	20,525	20,525

Source: Own estimation.
Notes. Coefficients reported. Standard errors in parentheses. Only main results displayed. Coefficient values of different models cannot be immediately compared due to varying samples.
[a]Suggested interpretation of interaction term.
*p < 0.05, **p < 0.01, ***p < 0.001.

Figure A.1. Relationship Between Polio Round Exposure and Child Age, Uttar Pradesh and Bihar.



Source: Own illustration.
Notes. Coefficients displayed. Full sample results for Uttar Pradesh based on Model 3 in Table 5.9, sub-samples estimated through Model 2 (slope based on *POLxAGE* interaction term). Full sample results for Bihar based on Model 6 in Table 5.9, sub-samples estimated through Model 5. Bar graph representing results for sub-samples of age groups (in months). Light-shaded bars are point estimates irrespective of significance level, dark-shaded bars with significance level of at least five per cent. *POLxAGE* coefficients for both states significant at the 0.1 per cent level. Sub-sample coefficients not immediately comparable due to different samples.

Appendix B: Detailed Results of Quantitative Analysis

This appendix presents the full results that lead to the findings presented in Section 3. Table B.1 depicts the full model and a selection of its nested variants. The Pseudo-R^2 and the Akaike Information Criterion (AIC) were used to assess the goodness-of-fit among various models. The Pseudo-R^2 measure compares the likelihood of the estimated model with the likelihood of a model that only includes a constant term, whereby higher values indicate a better model fit (Hilbe, 2009:244-245; McFadden, 1974:121). Conversely, a lower absolute AIC corresponds to a higher goodness-of-fit, here defined as the likelihood of the estimated model to produce true predictions, adjusted by the number of regressors and the sample size (Akaike, 1974:719; Hilbe, 2009:259-260). According to these tests, Model 3 of those depicted in Table B.1 represents the best fit to the underlying sample.

Table B.2 presents the interaction results. Models only including the interactions between polio round exposure and the survey round (*POLxSUR*) and between polio round exposure and the location of the household (*POLxURB*) do not show significant effects. In contrast, the *POLxAGE* and the *SURxPOLxAGE* interactions are statistically significant and improve model fitness. An *URBxPOLxAGE* interaction term (not shown) could not produce comparable results. Drawing on the *SURxPOLxAGE* interaction, Figure B.1 illustrates the predicted probability of full immunisation as it varies by polio rounds, child age, and survey round.

Table B.3 sub-divides the sample into age groups. This corresponds to assessing the interaction between polio round exposure and the age of the child, showing that all seven significant *pol* coefficients are negative, and that the vast majority of *pol* point estimates are negative as well (28 out of 31 estimates).

Appendix D explores the possibility of reverse causality, examining amongst others the model results for districts with low routine immunisation coverage. Tables B.4 to B.6 present detailed model results for these districts. To arrive at the bottom quintile, the districts were ranked according to their average immunisation coverage in the DLHS II, in the DLHS III, or across both surveys using the pooled sample. Eight different sets of "low-coverage" districts were selected, using Immunisation Index 1-coverage of children aged 10 to 30 month per district. For robust results, the same procedure was repeated, applying sample weights to the average immunisation coverage estimates, yielding four additional sets of "bottom-quintile" districts (indicated as "weighted," see Appendix D for details). The data demonstrate that the results can be replicated for a sub-sample only comprising the bottom-quintile immunisation coverage districts, given eight different interpretations of which districts the "bottom quintile" comprise.

Model results for Bihar are reported in Tables B.7 and B.8. The restricted and interaction models in Table B.7 indicate a more favourable relationship between polio intensity and full immunisation uptake. This also holds in the presence of interaction effects, whereby the relationship between the *pol* coefficient and the interaction terms suggests that negative effects only apply to a small portion of the sample. Similarly, the age-stratified results for the Bihar sample show that all significant results and the majority of the remaining point estimates are positive.

Table B.1. Selection of Regression Models, Uttar Pradesh.

Model No.	(1)	(2)	(3)	(4)	(5)
Model Description	**Full Model**		**Restricted Model**		
pol	-0.056*** (0.010)	-0.057*** (0.010)	-0.056*** (0.009)	-0.055*** (0.009)	-0.044*** (0.009)
ch_index	-0.045** (0.014)				
ch_sex	-0.123*** (0.030)	-0.123*** (0.030)	-0.139*** (0.028)	-0.142*** (0.028)	-0.168*** (0.027)
ch_age	0.076*** (0.006)	0.076*** (0.006)	0.075*** (0.005)	0.074*** (0.005)	0.053*** (0.005)
husb_school	0.032*** (0.004)	0.032*** (0.004)			
m_age_at_birth	0.013*** (0.003)	0.009** (0.003)	0.011*** (0.003)		
m_school	0.064*** (0.004)	0.066*** (0.004)	0.079*** (0.004)	0.080*** (0.004)	0.097*** (0.003)
m_anc	0.753*** (0.041)	0.753*** (0.041)	0.805*** (0.038)	0.820*** (0.038)	1.027*** (0.036)
m_pnc	0.181*** (0.033)	0.183*** (0.032)	0.183*** (0.031)		
ch_VACCadv	0.679*** (0.033)	0.683*** (0.033)	0.748*** (0.031)	0.757*** (0.031)	0.892*** (0.030)
ch_healtc_seen	1.875*** (0.040)	1.878*** (0.040)	1.877*** (0.038)	1.881*** (0.038)	
ch_healtc_notseen	1.058*** (0.036)	1.062*** (0.036)	1.121*** (0.034)	1.122*** (0.034)	
hh_size	0.001 (0.004)				
hh_SLI_quint	0.103*** (0.016)	0.107*** (0.015)	0.145*** (0.014)	0.151*** (0.014)	0.181*** (0.013)
hh_rel_notmuslim	0.336*** (0.046)	0.339*** (0.046)	0.372*** (0.042)	0.368*** (0.042)	0.487*** (0.040)
hh_caste_schedtribe	-0.109 (0.163)	-0.101 (0.163)	-0.062 (0.146)	-0.068 (0.145)	-0.125 (0.139)
hh_caste_OBC	-0.033 (0.039)	-0.030 (0.039)	-0.027 (0.037)	-0.022 (0.037)	-0.030 (0.035)
hh_caste_general	0.081 (0.048)	0.084 (0.048)	0.105* (0.046)	0.127** (0.046)	0.128** (0.044)
hh_rur_urb	0.153*** (0.042)	0.152*** (0.042)	0.110** (0.039)	0.138*** (0.039)	0.150*** (0.037)
survey_dummy	0.130 (0.082)	0.219** (0.077)	0.189** (0.072)	0.192** (0.071)	0.359*** (0.068)
Constant	-4.755*** (0.183)	-4.786*** (0.182)	-4.827*** (0.166)	-4.521*** (0.150)	-3.750*** (0.141)
N	28,916	28,916	34,327	34,327	34,328
k	90	88	87	85	83
df	89	87	86	84	82
***p*-Value**	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Pseudo R^2	0.237	0.236	0.248	0.247	0.182
AIC	0.970	0.970	0.919	0.920	0.999

Source: Own estimation.

Notes. Coefficients reported. Standard errors in parentheses. District dummy variables not displayed.

*p < 0.05, **p < 0.01, ***p < 0.001.

Table B.2. Results for Restricted and Interaction Models, Uttar Pradesh.

Model No.	(3)	(4)	(5)	(6)	(7)
Model Description	**Restricted Model**	**POLxAGE Interaction**	**POLxSUR Interaction**	**POLxURB Interaction**	**SURxPOLxAGE Interaction**
pol	-0.056*** (0.009)	0.037* (0.018)	-0.062*** (0.012)	-0.058*** (0.010)	0.099*** (0.020)
POLxAGE		-0.003*** (0.001)			-0.008*** (0.001)
POLxSUR			0.008 (0.009)		
POLxURB				0.006 (0.007)	
SURxPOLxAGE					0.002*** (0.000)
ch_sex	-0.139*** (0.028)	-0.137*** (0.028)	-0.139*** (0.028)	-0.139*** (0.028)	-0.135*** (0.028)
ch_age	0.075*** (0.005)	0.102*** (0.007)	0.075*** (0.005)	0.075*** (0.005)	0.140*** (0.009)
m_age_at_birth	0.011*** (0.003)	0.011*** (0.003)	0.011*** (0.003)	0.011*** (0.003)	0.011*** (0.003)
m_school	0.079*** (0.004)	0.079*** (0.004)	0.079*** (0.004)	0.079*** (0.004)	0.079*** (0.004)
m_anc	0.805*** (0.038)	0.805*** (0.038)	0.805*** (0.038)	0.804*** (0.038)	0.804*** (0.039)
m_pnc	0.183*** (0.031)	0.183*** (0.031)	0.183*** (0.031)	0.183*** (0.031)	0.184*** (0.031)
ch_VACCadv	0.748*** (0.031)	0.746*** (0.031)	0.748*** (0.031)	0.749*** (0.031)	0.743*** (0.031)
ch_healtc_seen	1.877*** (0.038)	1.869*** (0.038)	1.880*** (0.038)	1.877*** (0.038)	1.883*** (0.038)
ch_healtc_notseen	1.121*** (0.034)	1.122*** (0.034)	1.121*** (0.034)	1.121*** (0.034)	1.125*** (0.034)
hh_SLI_quint	0.145*** (0.014)	0.146*** (0.014)	0.145*** (0.014)	0.146*** (0.014)	0.145*** (0.014)
hh_rel_notmuslim	0.372*** (0.042)	0.374*** (0.042)	0.372*** (0.042)	0.373*** (0.042)	0.374*** (0.042)
hh_caste_schedtribe	-0.062 (0.146)	-0.056 (0.146)	-0.061 (0.146)	-0.062 (0.146)	-0.045 (0.146)
hh_caste_OBC	-0.027 (0.037)	-0.028 (0.037)	-0.027 (0.037)	-0.028 (0.037)	-0.027 (0.037)
hh_caste_general	0.105* (0.046)	0.105* (0.046)	0.105* (0.046)	0.105* (0.046)	0.103* (0.046)
hh_rur_urb	0.110** (0.039)	0.108** (0.039)	0.109** (0.039)	0.043 (0.085)	0.105** (0.039)
survey_dummy	0.189** (0.072)	0.053 (0.075)	0.117 (0.112)	0.191** (0.072)	-0.394*** (0.101)
Constant	-4.827*** (0.166)	-5.512*** (0.200)	-4.796*** (0.170)	-4.816*** (0.167)	-5.990*** (0.213)
N	34,327	34,327	34,327	34,327	34,327
k	87	88	89	89	89
df	86	87	87	87	88
***p*-Value**	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Pseudo R^2	0.248	0.249	0.248	0.248	0.250
AIC	0.919	0.918	0.919	0.919	0.917

Source: Own estimation.
Notes. Coefficients reported. Standard errors in parentheses. District dummy variables not displayed.
*p < 0.05, **p < 0.01, ***p < 0.001.

Table B.3. Model Results by Age Group Sub-Samples, Uttar Pradesh.

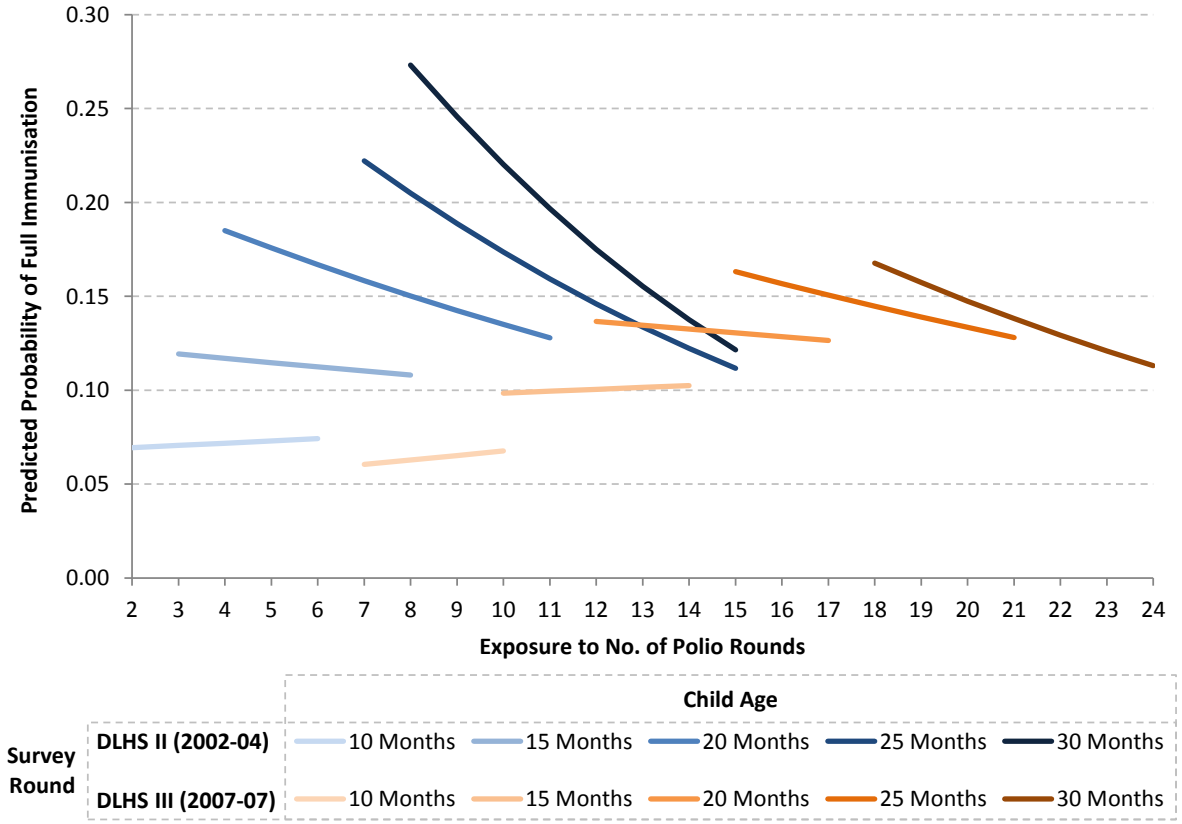
Age in Months	pol			*N*	Model-df	*p*-Value	Pseudo R^2	AIC
	b	se	*p*					
(10)	-0.149	(0.122)	(0.221)	1,548	84	< 0.001	0.243	0.813
(11)	-0.274*	(0.109)	(0.012)	1,324	82	< 0.001	0.263	0.903
(12)	-0.037	(0.096)	(0.699)	1,412	84	< 0.001	0.268	0.955
(13)	0.039	(0.072)	(0.591)	1,750	85	< 0.001	0.271	0.937
(14)	-0.017	(0.067)	(0.804)	1,564	85	< 0.001	0.300	0.933
(15)	-0.053	(0.057)	(0.352)	1,757	85	< 0.001	0.294	0.944
(16)	-0.089	(0.051)	(0.079)	1,818	85	< 0.001	0.295	0.961
(17)	-0.099*	(0.046)	(0.031)	1,911	85	< 0.001	0.264	1.015
(18)	-0.082	(0.048)	(0.088)	1,849	84	< 0.001	0.265	0.982
(19)	-0.097	(0.053)	(0.068)	1,850	85	< 0.001	0.332	0.936
(20)	-0.008	(0.055)	(0.885)	1,682	85	< 0.001	0.303	0.968
(21)	-0.116*	(0.057)	(0.040)	1,490	85	< 0.001	0.314	0.998
(22)	-0.005	(0.056)	(0.924)	1,391	85	< 0.001	0.304	0.996
(23)	-0.036	(0.052)	(0.491)	1,408	85	< 0.001	0.280	1.002
(24)	-0.129*	(0.058)	(0.027)	1,459	84	< 0.001	0.335	0.947
(25)	-0.119*	(0.049)	(0.016)	1,639	85	< 0.001	0.294	0.971
(26)	-0.156**	(0.053)	(0.003)	1,567	85	< 0.001	0.315	0.952
(27)	-0.133**	(0.051)	(0.009)	1,654	85	< 0.001	0.282	1.024
(28)	0.002	(0.060)	(0.978)	1,648	85	< 0.001	0.301	0.974
(29)	0.010	(0.062)	(0.870)	1,725	85	< 0.001	0.307	0.980
(30)	-0.045	(0.060)	(0.457)	1,749	84	< 0.001	0.285	0.990

Source: Own estimation.

Notes. Coefficients reported. Results for restricted model (Model 3 in Table B.1). Only polio round exposure variable shown. Only polio round exposure variable shown. Coefficient values of different models cannot be immediately compared due to varying samples.

*p < 0.05, **p < 0.01, ***p < 0.001

Figure B.1. Predicted Probability of Full Immunisation for Hypothetical Child.



Source: Own illustration.

Notes. Based on *SURxPOLxAGE* interaction model (Model 7 in Table B.2). Predicted values for hypothetical male child resident in district of Bareilly; with illiterate mother who has received ante- but no post-natal care, who received no advice to immunise child and does not possess vaccination card; living in second-to-last household wealth quintile in non-Muslim household; belonging to other backward class (OBC); and living in rural area. Survey round and age group varying as indicated. Range of polio round exposure based on minimum and maximum exposure for age group in respective survey round.

Table B.4. Results for Low Immunisation Coverage Districts, Restricted Model, Uttar Pradesh.

Selected Districts	Bottom Quintile of Combined Data Set		Bottom Quintile of DLHS II		Bottom Quintile of DHLS III		Intersection of DLHS II and DLHS III Bottom Quintiles	
District Ranking	**Unweighted**	**Weighted**	**Unweighted**	**Weighted**	**Unweighted**	**Weighted**	**Unweighted**	**Weighted**
pol	-0.081***	-0.087***	-0.081***	-0.067**	-0.074**	-0.090***	-0.109***	-0.112**
ch_sex	-0.211**	-0.166*	-0.151*	-0.184**	-0.177*	-0.177*	-0.220*	-0.338***
ch_age	0.089***	0.094***	0.093***	0.086***	0.089***	0.096***	0.104***	0.105***
m_age_at_birth	0.007	0.009	0.004	0.002	0.008	0.008	0.013	0.011
m_school	0.073***	0.072***	0.074***	0.075***	0.076***	0.080***	0.067***	0.069***
m_anc	1.014***	0.931***	0.870***	0.855***	0.980***	0.982***	0.985***	0.968***
m_pnc	0.292***	0.319***	0.411***	0.390***	0.315***	0.259**	0.393***	0.291**
ch_VACCadv	0.903***	0.906***	0.879***	0.836***	0.814***	0.790***	0.877***	0.679***
ch_healtc_seen	2.202***	2.252***	2.064***	2.068***	2.209***	2.286***	2.300***	2.412***
ch_healtc_notseen	0.881***	0.921***	0.995***	1.007***	1.064***	1.072***	0.938***	1.053***
hh_SLI_quint	0.177***	0.175***	0.151***	0.147***	0.154***	0.163***	0.216***	0.239***
hh_rel_notmuslim	0.322***	0.209*	0.192	0.192*	0.267**	0.265**	0.186	0.199
hh_caste_schtribe	0.074	0.208	0.229	0.439	0.184	0.110	-0.411	0.145
hh_caste_OBC	0.029	0.059	-0.135	-0.077	0.083	0.121	0.031	0.151
hh_caste_general	0.064	0.066	-0.012	0.040	0.140	0.177	0.061	0.172
hh_rur_urb	0.166	0.205*	0.273**	0.263**	0.222*	0.201*	0.248*	0.277*
survey_dummy	0.178	0.266	0.511**	0.452*	0.070	0.122	0.401	0.544*
Constant	-5.271***	-5.575***	-5.262***	-5.195***	-5.274***	-5.328***	-5.804***	-5.845***
N	7,959	7,845	7,639	7,658	8,009	8,025	5,174	4,696
k	37	37	37	37	37	37	37	37
df	30	30	30	30	30	30	25	24
***p*-Value**	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Pseudo R^2	0.259	0.258	0.257	0.257	0.266	0.270	0.270	0.279
AIC	0.689	0.691	0.714	0.717	0.690	0.690	0.642	0.628

Source. Own estimation.

Notes. Coefficients reported. Selected districts include both survey round, whereby ranking is according to coverage in DLHS II, DLHS III, or the combined sample. Weighted ranking based on immunisation coverage using sample weights. Different sample sizes owing to varying sample sizes per district. District dummy variables not displayed. Coefficient values of different models cannot be immediately compared due to varying samples. Immunisation coverage estimated using coverage rates of Immunisation Index 1 across children aged 10 to 30 months.

*p < 0.05, **p < 0.01, ***p < 0.001.

Table B.5. Results for Low Immunisation Coverage Districts, POLxAGE Model, Uttar Pradesh.

Selected Districts	Bottom Quintile of Combined Data Set		Bottom Quintile of DLHS II		Bottom Quintile of DHLS III		Intersection of DLHS II and DLHS III Bottom Quintiles	
District Ranking	**Unweighted**	**Weighted**	**Unweighted**	**Weighted**	**Unweighted**	**Weighted**	**Unweighted**	**Weighted**
pol	-0.006	0.018	-0.002	0.025	0.025	-0.014	-0.039	-0.028
POLxAGE	-0.003	-0.004**	-0.003*	-0.003*	-0.004*	-0.003*	-0.002	-0.003
ch_sex	-0.212**	-0.167*	-0.152*	-0.183**	-0.180**	-0.179*	-0.221*	-0.340***
ch_age	0.108***	0.120***	0.114***	0.110***	0.117***	0.117***	0.123***	0.129***
m_age_at_birth	0.007	0.009	0.004	0.002	0.008	0.008	0.013	0.011
m_school	0.073***	0.072***	0.074***	0.074***	0.076***	0.080***	0.067***	0.069***
m_anc	1.018***	0.938***	0.873***	0.858***	0.985***	0.987***	0.990***	0.974***
m_pnc	0.289***	0.314***	0.412***	0.390***	0.311***	0.254**	0.393***	0.293**
ch_VACCadv	0.902***	0.907***	0.874***	0.830***	0.810***	0.788***	0.873***	0.673***
ch_healtc_seen	2.192***	2.237***	2.057***	2.063***	2.198***	2.275***	2.288***	2.401***
ch_healtc_notseen	0.880***	0.920***	0.996***	1.010***	1.061***	1.069***	0.935***	1.051***
hh_SLI_quint	0.179***	0.177***	0.152***	0.148***	0.156***	0.165***	0.217***	0.239***
hh_rel_notmuslim	0.324***	0.210*	0.195*	0.197*	0.265**	0.263**	0.190	0.206
hh_caste_schtribe	0.077	0.213	0.230	0.445	0.192	0.118	-0.420	0.155
hh_caste_OBC	0.027	0.056	-0.136	-0.078	0.079	0.118	0.030	0.149
hh_caste_general	0.067	0.068	-0.008	0.045	0.141	0.177	0.066	0.178
hh_rur_urb	0.171	0.212*	0.279**	0.273**	0.224*	0.202*	0.253*	0.288*
survey_dummy	0.049	0.080	0.375	0.297	-0.079	-0.002	0.292	0.422
Constant	-5.849***	-6.344***	-5.882***	-5.913***	-6.049***	-5.903***	-6.344***	-6.496***
N	7,959	7,845	7,639	7,658	8,009	8,025	5,174	4,696
k	38	38	38	38	38	38	38	38
df	31	31	31	31	31	31	26	25
***p*-Value**	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Pseudo R^2	0.260	0.259	0.258	0.258	0.267	0.270	0.270	0.280
AIC	0.689	0.690	0.714	0.717	0.690	0.690	0.642	0.628

Source. Own estimation.

Notes. Coefficients reported. Selected districts include both survey round, whereby ranking is according to coverage in DLHS II, DLHS III, or the combined sample. Weighted ranking based on immunisation coverage using sample weights. Different sample sizes owing to varying sample sizes per district. District dummy variables not displayed. Coefficient values of different models cannot be immediately compared due to varying samples. Immunisation coverage estimated using coverage rates of Immunisation Index 1 across children aged 10 to 30 months.

*p < 0.05, **p < 0.01, ***p < 0.001.

Table B.6. Results for Low Immunisation Coverage Districts, SURxPOLxAGE Model, Uttar Pradesh.

Selected Districts	Bottom Quintile of Combined Data Set		Bottom Quintile of DLHS II		Bottom Quintile of DHLS III		Intersection of DLHS II and DLHS III Bottom Quintiles	
District Ranking	Unweighted	Weighted	Unweighted	Weighted	Unweighted	Weighted	Unweighted	Weighted
pol	0.044	0.052	0.056	0.080	0.061	0.030	0.011	0.016
POLxAGE	-0.007***	-0.007**	-0.008***	-0.008***	-0.007**	-0.006**	-0.007*	-0.007*
SURxPOLxAGE	0.002**	0.002	0.002**	0.002**	0.002*	0.002*	0.002*	0.002
ch_sex	-0.205**	-0.162*	-0.144*	-0.175*	-0.173*	-0.172*	-0.214*	-0.332***
ch_age	0.150***	0.146***	0.156***	0.152***	0.148***	0.149***	0.161***	0.158***
m_age_at_birth	0.007	0.009	0.004	0.002	0.008	0.008	0.013	0.010
m_school	0.073***	0.072***	0.074***	0.075***	0.076***	0.080***	0.066***	0.069***
m_anc	1.013***	0.934***	0.865***	0.850***	0.983***	0.986***	0.982***	0.968***
m_pnc	0.293***	0.316***	0.419***	0.395***	0.317***	0.259**	0.401***	0.295**
ch_VACCadv	0.906***	0.908***	0.881***	0.832***	0.813***	0.790***	0.889***	0.680***
ch_healtc_seen	2.216***	2.251***	2.073***	2.080***	2.217***	2.296***	2.306***	2.416***
ch_healtc_notseen	0.893***	0.927***	0.999***	1.014***	1.067***	1.079***	0.938***	1.058***
hh_SLI_quint	0.174***	0.174***	0.148***	0.143***	0.152***	0.160***	0.212***	0.234***
hh_rel_notmuslim	0.334***	0.213*	0.198*	0.202*	0.270**	0.268**	0.193	0.209
hh_caste_schtribe	0.135	0.249	0.264	0.485	0.235	0.157	-0.374	0.200
hh_caste_OBC	0.034	0.060	-0.124	-0.067	0.083	0.122	0.044	0.159
hh_caste_general	0.068	0.068	-0.002	0.051	0.141	0.178	0.070	0.182
hh_rur_urb	0.172	0.212*	0.281**	0.274**	0.226*	0.203*	0.258*	0.289*
survey_dummy	-0.376	-0.202	-0.098	-0.161	-0.387	-0.354	-0.126	0.070
Constant	-6.258***	-6.602***	-6.305***	-6.315***	-6.344***	-6.216***	-6.725***	-6.780***
N	7,959	7,845	7,639	7,658	8,009	8,025	5,174	4,696
k	39	39	39	39	39	39	39	39
df	32	32	32	32	32	32	27	26
p-Value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Pseudo R^2	0.261	0.259	0.259	0.259	0.267	0.271	0.271	0.281
AIC	0.688	0.690	0.713	0.716	0.690	0.689	0.641	0.628

Source. Own estimation.

Notes. Coefficients reported. Selected districts include both survey round, whereby ranking is according to coverage in DLHS II, DLHS III, or the combined sample. Weighted ranking based on immunisation coverage using sample weights. Different sample sizes owing to varying sample sizes per district. District dummy variables not displayed. Coefficient values of different models cannot be immediately compared due to varying samples. Immunisation coverage estimated using coverage rates of Immunisation Index 1 across children aged 10 to 30 months.

*p < 0.05, **p < 0.01, ***p < 0.001.

Table B.7. Results for Restricted and Interaction Models, Uttar Pradesh and Bihar.

	Uttar Pradesh			Bihar		
Model No.	**(3)**	**(4)**	**(6)**	**(7)**	**(8)**	**(9)**
Model Description	**Restricted Model**	**POLxAGE Interaction**	**SURxPOLxAGE Interaction**	**Restricted Model**	**POLxAGE Interaction**	**SURxPOLxAGE Interaction**
pol	-0.056*** (0.009)	0.037* (0.018)	0.099*** (0.020)	0.042*** (0.010)	0.119*** (0.020)	0.176*** (0.023)
POLxAGE		-0.003*** (0.001)	-0.008*** (0.001)		-0.003*** (0.001)	-0.007*** (0.001)
SURxPOLxAGE			0.002*** (0.000)			0.002*** (0.000)
ch_sex	-0.139*** (0.028)	-0.137*** (0.028)	-0.135*** (0.028)	-0.249*** (0.036)	-0.248*** (0.036)	-0.248*** (0.036)
ch_age	0.075*** (0.005)	0.102*** (0.007)	0.140*** (0.009)	0.026*** (0.006)	0.054*** (0.009)	0.082*** (0.011)
m_age_at_birth	0.011*** (0.003)	0.011*** (0.003)	0.011*** (0.003)	-0.001 (0.003)	-0.002 (0.003)	-0.002 (0.003)
m_school	0.079*** (0.004)	0.079*** (0.004)	0.079*** (0.004)	0.078*** (0.005)	0.079*** (0.005)	0.079*** (0.005)
m_anc	0.805*** (0.038)	0.805*** (0.038)	0.804*** (0.039)	0.436*** (0.045)	0.432*** (0.045)	0.435*** (0.045)
m_pnc	0.183*** (0.031)	0.183*** (0.031)	0.184*** (0.031)	0.269*** (0.040)	0.273*** (0.040)	0.275*** (0.040)
ch_VACCadv	0.748*** (0.031)	0.746*** (0.031)	0.743*** (0.031)	0.512*** (0.040)	0.510*** (0.040)	0.510*** (0.040)
ch_healtc_seen	1.877*** (0.038)	1.869*** (0.038)	1.883*** (0.038)	2.301*** (0.051)	2.294*** (0.051)	2.300*** (0.051)
ch_healtc_notseen	1.121*** (0.034)	1.122*** (0.034)	1.125*** (0.034)	1.773*** (0.049)	1.769*** (0.049)	1.768*** (0.049)
hh_SLI_quint	0.145*** (0.014)	0.146*** (0.014)	0.145*** (0.014)	0.137*** (0.019)	0.138*** (0.019)	0.138*** (0.019)
hh_rel_notmuslim	0.372*** (0.042)	0.374*** (0.042)	0.374*** (0.042)	0.629*** (0.058)	0.636*** (0.058)	0.635*** (0.058)
hh_caste_schedtribe	-0.062 (0.146)	-0.056 (0.146)	-0.045 (0.146)	-0.022 (0.152)	-0.026 (0.152)	-0.034 (0.152)
hh_caste_OBC	-0.027 (0.037)	-0.028 (0.037)	-0.027 (0.037)	0.289*** (0.048)	0.286*** (0.048)	0.291*** (0.048)
hh_caste_general	0.105* (0.046)	0.105* (0.046)	0.103* (0.046)	0.551*** (0.065)	0.552*** (0.065)	0.552*** (0.065)
hh_rur_urb	0.110** (0.039)	0.108** (0.039)	0.105** (0.039)	0.005 (0.058)	0.007 (0.058)	0.006 (0.058)
survey_dummy	0.189** (0.072)	0.053 (0.075)	-0.394*** (0.101)	0.463*** (0.082)	0.364*** (0.085)	-0.085 (0.121)
Constant	-4.827*** (0.166)	-5.512*** (0.200)	-5.990*** (0.213)	-5.944*** (0.200)	-6.648*** (0.258)	-7.027*** (0.268)
N	34,327	34,327	34,327	20,525	20,525	20,525
k	87	88	89	54	55	56
df	86	87	88	53	54	55
***p*-Value**	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Pseudo R^2	0.248	0.249	0.250	0.293	0.294	0.295
AIC	0.919	0.918	0.917	0.917	0.916	0.915

Source: Own estimation.

Notes. Coefficients reported. Standard errors in parentheses. District dummy variables not displayed. Coefficient values of different models cannot be immediately compared due to varying samples.

*p < 0.05, **p < 0.01, ***p < 0.001.

Table B.8. Model Results by Age Group Sub-Samples, Bihar.

Age in Months	pol			*N*	Model-df	*p*-Value	Pseudo R^2	AIC
	b	se	*p*					
(10)	0.233	(0.129)	(0.071)	731	51	< 0.001	0.239	0.963
(11)	0.069	(0.119)	(0.560)	568	50	< 0.001	0.332	0.992
(12)	0.127	(0.076)	(0.093)	1,013	52	< 0.001	0.273	0.968
(13)	0.003	(0.067)	(0.962)	1,338	52	< 0.001	0.296	0.930
(14)	0.010	(0.059)	(0.863)	1,301	52	< 0.001	0.331	0.911
(15)	0.132*	(0.062)	(0.035)	1,176	52	< 0.001	0.355	0.923
(16)	0.048	(0.057)	(0.401)	1,244	52	< 0.001	0.343	0.929
(17)	-0.001	(0.054)	(0.979)	1,160	52	< 0.001	0.304	1.005
(18)	0.142*	(0.060)	(0.017)	1,041	52	< 0.001	0.309	1.017
(19)	0.002	(0.068)	(0.979)	891	52	< 0.001	0.338	0.992
(20)	-0.115	(0.070)	(0.098)	736	51	< 0.001	0.319	1.042
(21)	0.064	(0.066)	(0.328)	727	52	< 0.001	0.358	1.000
(22)	0.086	(0.072)	(0.228)	685	51	< 0.001	0.350	0.987
(23)	0.078	(0.065)	(0.232)	641	52	< 0.001	0.388	0.986
(24)	0.051	(0.049)	(0.303)	973	52	< 0.001	0.409	0.872
(25)	0.022	(0.045)	(0.635)	1,112	52	< 0.001	0.357	0.922
(26)	0.045	(0.048)	(0.347)	1,063	52	< 0.001	0.375	0.899
(27)	0.078	(0.044)	(0.075)	1,038	52	< 0.001	0.341	0.970
(28)	0.023	(0.042)	(0.593)	1,039	52	< 0.001	0.362	0.953
(29)	0.043	(0.059)	(0.462)	1,025	52	< 0.001	0.382	0.939
(30)	0.066	(0.054)	(0.223)	954	52	< 0.001	0.332	1.005

Source: Own estimation.

Notes. Coefficients reported. Results for restricted model (Model 7 in Table B.5). Only polio round exposure variable shown. Coefficient values of different models cannot be immediately compared due to varying samples.

*p < 0.05, **p < 0.01, ***p < 0.001

Appendix C: Robustness Tests for Quantitative Results

Tables C.2 to C.5 present the results from the robustness tests for the aggregate models (i.e., the full model, the restricted model, and the two interaction models with *POLxAGE* and *SURxPOLxAGE* interactions). Sub-sections C.1 to C.5 briefly describe the implications of these robustness tests with reference to the respective columns in Tables C.2 to C.5. These tests include the use of alternative immunisation indices, the application of sample weights to the survey data, the estimation of standard errors that are robust to potential problems of clustering and heteroskedasticity, estimating varying subsamples based on the recall of immunisation information, and estimates with the different functional forms of probit and linear regressions. Overall, the results for the three-way interaction model are highly robust for all these tests, while the other models are partly sensitive to alternative immunisation indices and the recall of immunisation information. Appendix C.6 and Table C.6 explore a possible diminishing probability of full immunisation for older children, which may potentially affect the regression results. However, the augmented model demonstrates that the regression results remain the same, albeit the assumption of a diminishing probability of full immunisation for older children is supported.

C.1 Varying Immunisation Indices (Columns 1 to 4)

The primary immunisation index for estimating the regression model includes the three vaccines BCG, DPT (three doses), and measles. This index was selected because the HepB vaccine is only selectively deployed in the study region and because of concerns about recall biases and reverse causality when including the polio vaccine (OPV; see Appendix D).

Results for Indices 2 (BCG, DPT, HepB, measles), 3 (BCG, DPT, measles, OPV), and 4 (BCG, DPT, HepB, measles, OPV) are presented in Columns 2 to 4. Interestingly, aggregate results for the full and restricted model are not affected as far as the sign and significance of the polio round exposure coefficient are concerned, although occasional changes in the significance of control variable coefficients such as the survey dummy or age of mother at birth occur.

The *POLxAGE* interaction model is more sensitive to the use of alternative immunisation indices, specifically the introduction of the HepB vaccine. This suggests that HepB vaccine uptake, which is administered only to a very small portion of the sample, is affected by a higher exposure to polio rounds, and that this effect is independent of the age of the child. However, the tree-way interaction *SURxPOLxAGE* is robust against changes in the composition of the immunisation index. Despite small changes in significance levels of the *POLxAGE* coefficient from the 0.1 per cent level to the 1 per cent level for Index 2 and 4, respectively, the estimated positive impact of the survey round on the *POLxAGE* interaction persists.

C.2 Applying Sample Weights (Column 5)

The sample used to estimate the logistic regression models is based on an India-wide household survey. Although such surveys aspire representativeness, their samples often do not reflect the proportion of certain groups in the entire population. Therefore, such surveys provide sample weights in order to correct for biases that stem from over- or undersampling certain groups (e.g., rural and urban households). Through applying such sample weights to the regression model, the results may become more robust to such potential sampling biases (although this is not clear from the outset; Deaton,

1995:1792). This typically results in inflated standard errors (not shown), which potentially lowers the significance level of the estimated coefficients.

In the present case, sample weights are available for interviewed mothers and affect only the *pol*-coefficient at the age of zero months in the *POLxAGE* interaction model, which is not significant at the five per cent level anymore (the interaction term itself remains highly significant). The overall results of interest are robust to the application of sample weights.

C.3 Estimates With Robust Standard Errors (Columns 6 to 9)

Further robustness tests are appropriate if the underlying sample is suspected to be misspecified and thus to violate assumptions of the logistic regression. Such violations may result from correlated standard errors within certain "clusters" such as districts or villages, or from non-constant standard errors due to heteroskedasticity. Robust standard errors can be understood as conservative estimates to accommodate such violations.

To account for cluster-dependent variance in the model, standard errors are adjusted to the 70 district and 4,843 village clusters.[8] This assumes that the effects of the independent variables are correlated within districts or within villages. Columns 6 and 7 display the results for these clusters, which resemble the outcomes from the sample weight application above.

To account for potential violations of heteroskedasticity, Huber and White sandwich estimators and non-parametric bootstrapping were applied (White, 1980; Hilbe, 2009:136-142). Whereas the first method adjusts the model variance through "sandwiching" it between two model variance matrices, the second method draws repeated sub-samples to be compared with the overall model results (Hilbe, 2009:137, 139). Columns 7 and 8 report the results for these tests, showing no or little deviation from the preceding tests and, indeed, from the initial model results. Thus, even if model violations such as clustering and heteroskedasticity were present, this would not affect the presented results.

C.4 Recorded Versus Recall Data (Columns 10 to 12)

The immunisation index used in this investigation is based on documented information and parent recall. Both methods are fairly reliable measures for the child's immunisation status, albeit neither is fully accurate. In order to examine whether recall biases affect the results, Columns 10 to 12 present the model results for sub-samples including only documented data, only recall data based on existing vaccination cards, and only recall data without the possession of vaccination cards.

For the documented data and recall information without health card, the results of the full and restricted model without interaction do not hold as far as the significance of the *pol*-coefficient is concerned. Conversely, recall information from mothers who possess a vaccination card confirms the earlier results. For the *POLxAGE* interaction model, the recall without a vaccination card does not exhibit significant interaction, whereas the children of mothers with a health card do so at the 1 and 0.1 per cent level for documented and recall information, respectively. In a three-way *SURxPOLxAGE* interaction, all results become significant again, supporting the statement that all these variables are significant explanatory factors for full immunisation attainment.

It is not immediately obvious how the varying sources affect children's immunisation response to being exposed to additional polio immunisation rounds. In-

[8] Villages cannot be matched across surveys due to lacking identifiers.

direct factors are a likely explanation, especially the different composition of these sub-samples: Mothers with health cards are a group that is somewhat different from mothers without health cards. Children in households with vaccination cards do not only exhibit a larger overall proportion of vaccinated children (59% and 41% for shown and not shown vaccination card versus 13% for households without card; Index 1), but their mothers are better educated, more likely to have received ante- and post-natal care and their households are wealthier and more likely to be non-Muslim. In addition, these households are overrepresented in the more recent survey round (see Table C.1 below). The results for these subsamples are thus less likely to be caused by differences in recall as by differences in group composition. The interaction effect with the survey round can capture a part of these composition effects and changes in the *pol* and *POLxAGE* response across surveys, which helps explain why all results can be replicated in this model. Due to its robustness, it is fair to conclude that these variables and interaction terms are important explanatory variables for full immunisation uptake. However, the specific responses for the aggregate models remain a puzzle to some extent.

Table C.1. Comparison of Sub-Sample Means by Immunisation Information.

	As Recorded on Health Card	Recall From Health Card	Recall Without Health Card
Immunisation Index 1 (BCG, DPT, Mea.)	0.59 (0.49)	0.41 (0.49)	0.13 (0.34)
Immunisation Index 2 (BCG, DPT, HepB, Mea.)	0.13 (0.33)	0.09 (0.29)	0.02 (0.14)
Immunisation Index 3 (BCG, DPT, Mea., OPV)	0.58 (0.49)	0.41 (0.49)	0.13 (0.34)
Immunisation Index 4 (BCG, DPT, HepB, Mea., OPV)	0.13 (0.33)	0.09 (0.29)	0.02 (0.14)
pol	11.89 (4.38)	11.99 (5.03)	11.12 (5.08)
ch_sex	0.45 (0.5)	0.47 (0.5)	0.49 (0.5)
ch_age	18.69 (5.84)	20.62 (6.01)	20.40 (6.05)
m_age_at_birth	24.19 (5.14)	24.43 (5.2)	25.18 (5.78)
m_school	4.59 (5.19)	4.03 (5.01)	1.75 (3.47)
m_anc	0.84 (0.37)	0.78 (0.41)	0.57 (0.5)
m_pnc	0.53 (0.5)	0.48 (0.5)	0.32 (0.47)
hh_SLI_quint	3.02 (1.32)	2.89 (1.32)	2.41 (1.16)
hh_rel_notmuslim	0.86 (0.34)	0.84 (0.37)	0.77 (0.42)
hh_rur_urb	0.22 (0.41)	0.22 (0.42)	0.18 (0.39)
survey_dummy	0.70 (0.46)	0.57 (0.49)	0.46 (0.5)
N	7,704	10,844	19,897

Source: Own estimation.

Notes. Uttar Pradesh only. Aggregate values on the child level. Standard errors in parentheses. With the exception of *pol* and *hh_rur_urb* (between health card seen / not seen groups), all three groups are significantly different in all categories at least at the 1 per cent level.

C.5 Alternative Functional Forms (Columns 13 and 14)

Alternative functional forms of the regression model have been tested to assess the robustness of the specification. In Column 13, a probit regression model is estimated, which is similar to the logit model yet assumes a binary response that is distributed according to the cumulative density function of the normal distribution (rather than the logistic cumulative distribution function as in the logit case; Greene, 2009:773-774; Wooldridge, 2010:566). Although both approaches are very similar, differences in the underlying sample distribution can yield subtle differences in the parameter estimates.

Column 14 estimates a linear probability model based on linear multiple regression using ordinary least squares (Wooldridge, 2010:562-565). Although such models yield potentially inefficient estimators in the presence of binary response data compared to logit and probit models, they can provide a useful alternative perspective on the partial effects of the independent variables (Agresti and Finlay, 2009:484; Greene, 2008:772-773, 782; Wooldridge, 2010:562-565).

The results show a high level of consistency with the logistic regression. For all four models (full, restricted, *POLxAGE*, and *SURxPOLxAGE*), the main results are replicated and the overwhelming majority of control variables do not show any differences. This lends confidence to the view that the model is correctly specified.

C.6 Diminishing Probability of Full Immunisation for Older Children

The main text has suggested that a counterargument to the observed impact of the PEI on routine immunisation in Uttar Pradesh is a possible diminishing (marginal) probability of full immunisation for older children. This may stem from changes in the quality of recall data or from a diminishing willingness of parents to immunise their child. To formally assess whether such an effect is present, a squared child age term is introduced into the regression model (the original child age term remains in the model). If the assumption is correct, the coefficient of the squared age term is negative (indicating diminishing effects at higher ages), while the coefficient of the regular child age term remains positive.

The main results of this exercise are presented in Table C.6, amending the full, the restricted, the *POLxAGE*, and the *SURxPOLxAGE* regression model with the squared child age term (and the respective interactions). The results show that the additional term enhances model fitness and that the coefficient of the squared age term is slightly negative. This supports the assumption that older children may be more likely to be fully immunised than younger children, but not proportionally so. The positive and significant $POLxAGE^2$ interaction term suggests that the increasingly adverse effects on older children level off at higher ages. Finally, the $SURxPOLxAGE^2$ interaction term indicates that the curvature of the age-specific response decreases across survey rounds; that is, the effect is less pronounced over time.

Although these results indicate that the "diminishing willingness to immunise"-assumption is valid, the overall results of the statistical analysis remain the same: When exposed to an additional polio immunisation round, children's probability to receive full immunisation is decreased, and this applies especially to older children.

Table C.2. Robustness Tests for Full Regression Model.

Full Model	Varying Immunisation Indices				Sample Weights	Robust Standard Errors				Immunisation Recall			Functional Form	
	1: BCG, DPT, Mea.	2: BCG, DPT, HepB, Mea.	3: BCG, DPT, Mea., OPV	4: BCG, DPT, HepB, Mea., OPV		District-wise clustering	Village-wise clustering	Sandwich estimator (Huber/ White)	Bootstrap estimation	As Recorded on Health Card	Recall From Health Card	Recall Without Health Card	Probit Model	Linear Model
Column No.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
pol	-0.056***	-0.078***	-0.045***	-0.070***	-0.057***	-0.056***	-0.055***	-0.056***	-0.056***	-0.032	-0.059***	-0.018	-0.032***	-0.009***
ch_index	-0.045**	-0.072**	-0.050***	-0.074**	-0.034*	-0.045**	-0.027	-0.045**	-0.045***	-0.018	-0.054*	-0.056*	-0.025**	-0.006**
ch_sex	-0.123***	-0.219***	-0.128***	-0.227***	-0.120***	-0.123***	-0.134***	-0.123***	-0.123***	-0.204***	-0.031	-0.187***	-0.074***	-0.019***
ch_age	0.076***	0.093***	0.072***	0.089***	0.078***	0.076***	0.074***	0.076***	0.076***	0.077***	0.069***	0.063***	0.044***	0.012***
husb_school	0.032***	0.054***	0.032***	0.054***	0.031***	0.032***	0.030***	0.032***	0.032***	0.030***	0.020**	0.050***	0.019***	0.005***
m_age_at_birth	0.013***	0.010	0.016***	0.012	0.013***	0.013***	0.010**	0.013***	0.013***	0.018**	0.014**	0.013*	0.007***	0.002***
m_school	0.064***	0.087***	0.060***	0.086***	0.067***	0.064***	0.060***	0.064***	0.064***	0.051***	0.065***	0.075***	0.038***	0.013***
m_anc	0.753***	0.388***	0.739***	0.407***	0.779***	0.753***	0.741***	0.753***	0.753***	0.323***	0.533***	1.261***	0.440***	0.095***
m_pnc	0.181***	0.126*	0.176***	0.126*	0.171***	0.181***	0.139***	0.181***	0.181***	0.139*	0.187***	0.199***	0.107***	0.033***
ch_VACCadv	0.679***	0.600***	0.675***	0.603***	0.679***	0.679***	0.697***	0.679***	0.679***	0.302***	0.483***	1.304***	0.403***	0.110***
ch_healtc_seen	1.875***	1.255***	1.832***	1.234***	1.856***	1.875***	1.903***	1.875***	1.875***				1.114***	0.345***
ch_healtc_notseen	1.058***	0.901***	1.002***	0.839***	1.041***	1.058***	1.021***	1.058***	1.058***				0.629***	0.174***
hh_size	0.001	-0.006	0.001	-0.008	0.000	0.001	0.008	0.001	0.001	-0.020**	0.007	0.006	0.001	0.000
hh_SLI_quint	0.103***	0.139***	0.093***	0.129***	0.097***	0.103***	0.094***	0.103***	0.103***	0.110***	0.089***	0.141***	0.060***	0.018***
hh_rel_notmuslim	0.336***	0.072	0.330***	0.043	0.315***	0.336***	0.330***	0.336***	0.336***	0.290**	0.316***	0.397***	0.191***	0.052***
hh_caste_schedtribe	-0.109	-0.102	-0.047	-0.002	-0.189	-0.109	-0.073	-0.109	-0.109	0.242	-0.359	-0.404	-0.069	-0.017
hh_caste_OBC	-0.033	-0.085	-0.026	-0.094	-0.049	-0.033	-0.034	-0.033	-0.033	0.055	-0.043	-0.059	-0.018	-0.002
hh_caste_general	0.081	-0.063	0.088	-0.068	0.080	0.081	0.086	0.081	0.081	0.138	0.005	0.165	0.049	0.017*
hh_rur_urb	0.153***	0.228***	0.163***	0.276***	0.130**	0.153**	-0.896	0.153***	0.153***	0.187*	0.286***	0.004	0.088***	0.026***
survey_dummy	0.130	0.525***	0.061	0.463**	0.164	0.130	0.167	0.130	0.130	0.736***	-0.179	-0.450**	0.069	0.018
Constant	-4.755***	-6.160***	-4.709***	-6.082***	-4.677***	-4.755***	-4.797***	-4.755***	-4.755***	-2.766***	-2.711***	-6.439***	-2.794***	-0.285***
N	28,916	28,326	27,253	26,746	28,916	28,916	23,041	28,916	28,916	6,101	8,868	13,947	28,916	28,916
k	90	90	90	90	90	90	90	90	90	90	90	90	90	90
df	89	89	89	89	89	19	89	89	49	87	87	87	89	89
p-Value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001		< 0.001	< 0.001		< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Pseudo R^2	0.237	0.204	0.229	0.202	0.236	0.237	0.220	0.237	0.237	0.0906	0.129	0.219	0.239	0.266
AIC	0.970	0.407	0.983	0.407	0.964	0.965	0.960	0.970	0.967	1.253	1.205	0.660	0.967	1.015

Source: Own estimation.

Notes. Coefficients reported. Chi^2 and *p*-value for district-level clustering and bootstrapping not reported. Linear model reporting adjusted R^2 instead of pseudo-R^2. District dummy variables not displayed. Coefficient values of different models cannot be immediately compared due to varying samples.

*p < 0.05, **p < 0.01, ***p < 0.001.

Table C.3. Robustness Tests for Restricted Regression Model.

Restricted Model	Varying Immunisation Indices				Sample Weights	Robust Standard Errors				Immunisation Recall			Functional Form	
	1: BCG, DPT, Mea.	2: BCG, DPT, HepB, Mea.	3: BCG, DPT, Mea., OPV	4: BCG, DPT, HepB, Mea., OPV		District-wise clustering	Village-wise clustering	Sandwich estimator (Huber/ White)	Bootstrap estimation	As Recorded on Health Card	Recall From Health Card	Recall Without Health Card	Probit Model	Linear Model
Column No.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
pol	-0.056***	-0.090***	-0.046***	-0.081***	-0.057***	-0.056***	-0.058***	-0.056***	-0.056***	-0.032	-0.073***	-0.015	-0.031***	-0.008***
ch_sex	-0.139***	-0.240***	-0.145***	-0.246***	-0.142***	-0.139***	-0.145***	-0.139***	-0.139***	-0.206***	-0.072	-0.184***	-0.082***	-0.020***
ch_age	0.075***	0.097***	0.071***	0.093***	0.076***	0.075***	0.074***	0.075***	0.075***	0.074***	0.076***	0.059***	0.042***	0.011***
m_age_at_birth	0.011***	0.007	0.012***	0.008	0.011***	0.011***	0.008**	0.011***	0.011***	0.015**	0.012**	0.009*	0.006***	0.002***
m_school	0.079***	0.110***	0.074***	0.109***	0.081***	0.079***	0.073***	0.079***	0.079***	0.063***	0.074***	0.098***	0.047***	0.016***
m_anc	0.805***	0.469***	0.796***	0.493***	0.812***	0.805***	0.781***	0.805***	0.805***	0.337***	0.570***	1.292***	0.465***	0.093***
m_pnc	0.183***	0.145*	0.175***	0.144*	0.175***	0.183***	0.139***	0.183***	0.183***	0.152*	0.186***	0.196***	0.107***	0.031***
ch_VACCadv	0.748***	0.704***	0.751***	0.717***	0.750***	0.748***	0.763***	0.748***	0.748***	0.324***	0.535***	1.392***	0.441***	0.116***
ch_healtc_seen	1.877***	1.308***	1.840***	1.292***	1.853***	1.877***	1.885***	1.877***	1.877***				1.110***	0.339***
ch_healtc_notseen	1.121***	0.967***	1.069***	0.912***	1.095***	1.121***	1.074***	1.121***	1.121***				0.660***	0.178***
hh_SLI_quint	0.145***	0.187***	0.138***	0.176***	0.136***	0.145***	0.140***	0.145***	0.145***	0.129***	0.125***	0.197***	0.084***	0.023***
hh_rel_notmuslim	0.372***	0.140	0.366***	0.110	0.357***	0.372***	0.359***	0.372***	0.372***	0.346***	0.324***	0.453***	0.209***	0.053***
hh_caste_schedtribe	-0.062	-0.143	-0.008	-0.054	-0.126	-0.062	-0.060	-0.062	-0.062	0.143	-0.189	-0.200	-0.044	-0.007
hh_caste_OBC	-0.027	-0.074	-0.022	-0.086	-0.049	-0.027	-0.035	-0.027	-0.027	0.040	-0.025	-0.059	-0.015	-0.001
hh_caste_general	0.105*	-0.035	0.114*	-0.042	0.108*	0.105	0.121*	0.105*	0.105*	0.145	0.030	0.202*	0.064*	0.020**
hh_rur_urb	0.110**	0.183**	0.118**	0.227***	0.093*	0.110*	-1.001	0.110**	0.110**	0.216**	0.240***	-0.075	0.061**	0.018**
survey_dummy	0.189**	0.622***	0.136	0.559***	0.201*	0.189	0.210*	0.189**	0.189**	0.762***	-0.002	-0.469***	0.090*	0.012
Constant	-4.827***	-6.307***	-4.798***	-6.247***	-4.743***	-4.827***	-4.780***	-4.827***	-4.827***	-2.831***	-2.792***	-6.154***	-2.809***	-0.259***
N	34,327	33,735	32,631	32,123	34,327	34,327	27,249	34,327	34,327	6,520	9,838	17,969	34,327	34,327
k	87	87	87	87	87	87	87	87	87	87	87	87	87	87
df	86	86	86	86	86	16	86	86	49	84	84	84	86	86
p-Value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001		< 0.001	< 0.001		< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Pseudo R^2	0.248	0.214	0.242	0.213	0.247	0.248	0.230	0.248	0.248	0.0936	0.126	0.217	0.250	0.273
AIC	0.919	0.369	0.927	0.367	0.917	0.915	0.910	0.919	0.917	1.255	1.201	0.610	0.916	0.954

Source: Own estimation.

Notes. Coefficients reported. Chi² and *p*-value for district-level clustering and bootstrapping not reported. Linear model reporting adjusted R^2 instead of pseudo-R^2. District dummy variables not displayed. Coefficient values of different models cannot be immediately compared due to varying samples.

*p < 0.05, **p < 0.01, ***p < 0.001.

Table C.4. Robustness Tests for POLxAGE Interaction Model.

Restricted Interaction Model (POLxAGE)	Varying Immunisation Indices				Sample Weights	Robust Standard Errors				Immunisation Recall			Functional Form	
	1: BCG, DPT, Mea.	2: BCG, DPT, HepB, Mea.	3: BCG, DPT, Mea., OPV	4: BCG, DPT, HepB, Mea., OPV		District-wise clustering	Village-wise clustering	Sandwich estimator (Huber/ White)	Bootstrap estimation	As Recorded on Health Card	Recall From Health Card	Recall Without Health Card	Probit Model	Linear Model
Column No.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
pol	0.037*	-0.050	0.044*	-0.035	0.037	0.037	0.034	0.037*	0.037*	0.098**	-0.006	0.007	0.020	0.003
POLxAGE	-0.003***	-0.001	-0.003***	-0.002	-0.003***	-0.003***	-0.003***	-0.003***	-0.003***	-0.005***	-0.002**	-0.001	-0.002***	-0.000***
ch_sex	-0.137***	-0.240***	-0.143***	-0.246***	-0.140***	-0.137***	-0.142***	-0.137***	-0.137***	-0.205***	-0.071	-0.184***	-0.081***	-0.020***
ch_age	0.102***	0.108***	0.096***	0.105***	0.103***	0.102***	0.103***	0.102***	0.102***	0.121***	0.095***	0.065***	0.057***	0.014***
m_age_at_birth	0.011***	0.008	0.012***	0.009	0.011***	0.011***	0.009**	0.011***	0.011***	0.015**	0.012**	0.009*	0.006***	0.002***
m_school	0.079***	0.110***	0.075***	0.109***	0.081***	0.079***	0.074***	0.079***	0.079***	0.064***	0.074***	0.098***	0.047***	0.016***
m_anc	0.805***	0.469***	0.796***	0.494***	0.813***	0.805***	0.782***	0.805***	0.805***	0.341***	0.569***	1.292***	0.465***	0.093***
m_pnc	0.183***	0.145*	0.176***	0.144*	0.175***	0.183***	0.139***	0.183***	0.183***	0.161**	0.187***	0.195***	0.107***	0.031***
ch_VACCadv	0.746***	0.702***	0.749***	0.715***	0.749***	0.746***	0.760***	0.746***	0.746***	0.320***	0.534***	1.390***	0.440***	0.116***
ch_healtc_seen	1.869***	1.304***	1.831***	1.287***	1.845***	1.869***	1.875***	1.869***	1.869***				1.104***	0.337***
ch_healtc_notseen	1.122***	0.967***	1.070***	0.912***	1.097***	1.122***	1.074***	1.122***	1.122***				0.660***	0.178***
hh_SLI_quint	0.146***	0.187***	0.139***	0.176***	0.137***	0.146***	0.141***	0.146***	0.146***	0.131***	0.126***	0.197***	0.085***	0.023***
hh_rel_notmuslim	0.374***	0.140	0.369***	0.111	0.359***	0.374***	0.362***	0.374***	0.374***	0.350***	0.326***	0.453***	0.211***	0.053***
hh_caste_schedtribe	-0.056	-0.142	-0.001	-0.053	-0.121	-0.056	-0.050	-0.056	-0.056	0.160	-0.187	-0.199	-0.042	-0.006
hh_caste_OBC	-0.028	-0.074	-0.023	-0.087	-0.050	-0.028	-0.035	-0.028	-0.028	0.043	-0.027	-0.059	-0.016	-0.001
hh_caste_general	0.105*	-0.035	0.114*	-0.043	0.108*	0.105	0.122*	0.105*	0.105*	0.145	0.028	0.202*	0.064*	0.020**
hh_rur_urb	0.108**	0.182**	0.117**	0.226***	0.092*	0.108*	-0.968	0.108**	0.108**	0.218**	0.240***	-0.075	0.060**	0.018**
survey_dummy	0.053	0.555***	0.005	0.481***	0.064	0.053	0.083	0.053	0.053	0.599***	-0.110	-0.499***	0.016	-0.005
Constant	-5.512***	-6.588***	-5.456***	-6.571***	-5.430***	-5.512***	-5.488***	-5.512***	-5.512***	-3.864***	-3.282***	-6.306***	-3.177***	-0.338***
N	34,327	33,735	32,631	32,123	34,327	34,327	27,249	34,327	34,327	6,520	9,838	17,969	34,327	34,327
k	88	88	88	88	88	88	88	88	88	88	88	88	88	88
df	87	87	87	87	87	17	87	87	49	85	85	85	87	87
p-Value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001		< 0.001	< 0.001		< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Pseudo R^2	0.249	0.214	0.243	0.213	0.248	0.249	0.231	0.249	0.249	0.0962	0.127	0.217	0.251	0.274
AIC	0.917	0.369	0.925	0.367	0.915	0.912	0.907	0.917	0.914	1.245	1.199	0.610	0.914	0.952

Source: Own estimation.

Notes. Coefficients reported. Chi^2 and *p*-value for district-level clustering and bootstrapping not reported. Linear model reporting adjusted R^2 instead of pseudo-R^2. District dummy variables not displayed. Coefficient values of different models cannot be immediately compared due to varying samples.

*p < 0.05, **p < 0.01, ***p < 0.001.

Table C.5. Robustness Tests for SURxPOLxAGE Interaction Model.

Restricted Interaction Model (SURxPOLxAGE)	Varying Immunisation Indices				Sample Weights	Robust Standard Errors				Immunisation Recall			Functional Form	
	1: BCG, DPT, Mea.	2: BCG, DPT, HepB, Mea.	3: BCG, DPT, Mea., OPV	4: BCG, DPT, HepB, Mea., OPV		District-wise clustering	Village-wise clustering	Sandwich estimator (Huber/ White)	Bootstrap estimation	As Recorded on Health Card	Recall From Health Card	Recall Without Health Card	Probit Model	Linear Model
Column No.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
pol	0.099***	-0.005	0.105***	0.009	0.098***	0.099***	0.096***	0.099***	0.099***	0.190***	0.048	0.067	0.055***	0.013***
POLxAGE	-0.008***	-0.005**	-0.008***	-0.005**	-0.008***	-0.008***	-0.008***	-0.008***	-0.008***	-0.014***	-0.006***	-0.005**	-0.004***	-0.001***
SURxPOLxAGE	0.002***	0.002**	0.002***	0.002*	0.002***	0.002***	0.002***	0.002***	0.002***	0.004***	0.002***	0.002**	0.001***	0.000***
ch_sex	-0.135***	-0.238***	-0.141***	-0.244***	-0.138***	-0.135***	-0.141***	-0.135***	-0.135***	-0.201***	-0.071	-0.182***	-0.079***	-0.020***
ch_age	0.140***	0.133***	0.134***	0.130***	0.141***	0.140***	0.141***	0.140***	0.140***	0.193***	0.126***	0.099***	0.078***	0.020***
m_age_at_birth	0.011***	0.008	0.012***	0.009	0.011***	0.011***	0.008**	0.011***	0.011***	0.015**	0.012**	0.009*	0.006***	0.002***
m_school	0.079***	0.110***	0.075***	0.109***	0.081***	0.079***	0.074***	0.079***	0.079***	0.064***	0.074***	0.098***	0.047***	0.016***
m_anc	0.804***	0.466***	0.795***	0.491***	0.811***	0.804***	0.780***	0.804***	0.804***	0.340***	0.572***	1.288***	0.464***	0.093***
m_pnc	0.184***	0.144*	0.177***	0.143*	0.175***	0.184***	0.141***	0.184***	0.184***	0.163**	0.188***	0.195***	0.107***	0.031***
ch_VACCadv	0.743***	0.701***	0.747***	0.713***	0.746***	0.743***	0.758***	0.743***	0.743***	0.321***	0.531***	1.387***	0.438***	0.115***
ch_healtc_seen	1.883***	1.313***	1.846***	1.297***	1.861***	1.883***	1.889***	1.883***	1.883***				1.113***	0.339***
ch_healtc_notseen	1.125***	0.972***	1.073***	0.916***	1.101***	1.125***	1.077***	1.125***	1.125***				0.662***	0.178***
hh_SLI_quint	0.145***	0.186***	0.138***	0.176***	0.135***	0.145***	0.141***	0.145***	0.145***	0.130***	0.125***	0.196***	0.084***	0.023***
hh_rel_notmuslim	0.374***	0.140	0.369***	0.111	0.358***	0.374***	0.360***	0.374***	0.374***	0.360***	0.324***	0.453***	0.211***	0.053***
hh_caste_schedtribe	-0.045	-0.139	0.010	-0.050	-0.110	-0.045	-0.038	-0.045	-0.045	0.170	-0.185	-0.175	-0.034	-0.005
hh_caste_OBC	-0.027	-0.075	-0.022	-0.088	-0.049	-0.027	-0.033	-0.027	-0.027	0.043	-0.026	-0.058	-0.015	-0.001
hh_caste_general	0.103*	-0.036	0.112*	-0.045	0.106*	0.103	0.120*	0.103*	0.103	0.138	0.027	0.203*	0.063*	0.020**
hh_rur_urb	0.105**	0.180**	0.114**	0.225***	0.089*	0.105*	-0.971	0.105**	0.105**	0.225**	0.237***	-0.079	0.058*	0.017**
survey_dummy	-0.394***	0.227	-0.438***	0.156	-0.380***	-0.394***	-0.369**	-0.394***	-0.394***	-0.122	-0.491**	-0.933***	-0.237***	-0.076***
Constant	-5.990***	-6.914***	-5.935***	-6.898***	-5.897***	-5.990***	-5.956***	-5.990***	-5.990***	-4.638***	-3.677***	-6.781***	-3.451***	-0.416***
N	34,327	33,735	32,631	32,123	34,327	34,327	27,249	34,327	34,327	6,520	9,838	17,969	34,327	34,327
k	89	89	89	89	89	89	89	89	89	89	89	89	89	89
df	88	88	88	88	88	18	88	88	49	86	86	86	88	88
p-Value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001		< 0.001	< 0.001		< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Pseudo R^2	0.250	0.215	0.244	0.213	0.249	0.250	0.232	0.250	0.250	0.101	0.128	0.218	0.252	0.275
AIC	0.917	0.369	0.925	0.367	0.915	0.912	0.907	0.917	0.914	1.245	1.199	0.610	0.914	0.952

Source: Own estimation.

Notes. Coefficients reported. Chi² and *p*-value for district-level clustering and bootstrapping not reported. Linear model reporting adjusted R^2 instead of pseudo-R^2. District dummy variables not displayed. Coefficient values of different models cannot be immediately compared due to varying samples.

*p < 0.05, **p < 0.01, ***p < 0.001.

Table C.6. Main Results for Diminishing Probability of Immunisation, Uttar Pradesh.

Model Description	Amended Full Model	Amended Restricted Model	Amended POLxAGE Interaction	Amended SURxPOLxAGE Interaction
pol	-0.058*** (0.010)	-0.059*** (0.010)	0.128** (0.049)	0.268*** (0.065)
ch_age	0.255*** (0.020)	0.250*** (0.019)	0.438*** (0.048)	0.483*** (0.056)
ch_age²	-0.004*** (0.000)	-0.004*** (0.000)	-0.009*** (0.001)	-0.010*** (0.002)
POLxAGE			-0.019*** (0.004)	-0.033*** (0.006)
POLxAGE²			0.000*** (0.000)	0.001*** (0.000)
SURxPOLxAGE				0.006** (0.002)
SURxPOLxAGE²				-0.000** (0.000)
N	28,916	34,327	34,327	34,327
k	91	88	90	93
df	90	87	89	91
***p*-Value**	< 0.001	< 0.001	< 0.001	< 0.001
Pseudo R²	0.239	0.251	0.251	0.251
AIC	0.967	0.916	0.916	0.916

Source: Own estimation.
Notes. Coefficients reported. Standard errors in parentheses. District dummy variables not displayed. Coefficient values of different models cannot be immediately compared due to varying samples.
*p < 0.05, **p < 0.01, ***p < 0.001.

Appendix D: Exploring Directions of Causality in the Quantitative Results

This appendix explores the causal relationships underlying the quantitative results. The present investigation suggests that polio eradication activities have a negative effect on routine immunisation uptake. However, high-ranking members of the NPSP argued in informal discussions that polio eradication activities become more intense where routine immunisation coverage is low. In other words, low immunisation coverage *causes* high polio eradication intensity, rather than being caused by it. Any negative association between the two may thus be prone to judgements of reverse causation. The tests in this appendix follow the argument that, although polio vaccine and full immunisation uptake are correlated amongst children, their immunisation status is unlikely to attract a higher exposure to the polio eradication activities. Moreover, among homogenous groups of districts that exhibit low routine immunisation coverage, the reverse causality argument would suggest that there is no variance in polio programme intensity, so that the link between programme exposure and immunisation uptake would vanish. The analysis of this sub-sample of districts shows that this is not the case. Although not a conclusive proof, this appendix therefore suggests that the argument of reverse causation is implausible: high polio eradication intensity likely causes low immunisation attainment.

The principal argument underlying the reverse causality claim is that polio eradication activities gravitate towards regions with low routine immunisation coverage. According to this line of argument, additional polio immunisation activities through the Polio Eradication Initiative are required when low routine immunisation coverage is insufficient to raise population immunity against poliomyelitis to sufficiently high levels.

This hints at a first problem. Population immunity against poliomyelitis depends on the routine *polio* immunisation coverage rather than *full* routine immunisation coverage. Thus, it appears more plausible that polio eradication activities are directed towards those regions where the coverage of the oral polio vaccine (OPV) is low. However, because the present study uses a full immunisation index which *excludes* OPV, this argument only holds if OPV coverage and full immunisation coverage are highly correlated. Table D1 explores this possibility through an analysis of the correlation between OPV uptake and the four immunisation indices, showing that the correlation between OPV and Immunisation Index 1 (the main dependent variable) is moderate to strong. Therefore, the possibility that polio eradication intensity is higher where full immunisation coverage is lower cannot be ruled out at this point.[1]

However, this study does not focus on a high polio eradication intensity *per se*, but on the exposure to the polio programme. Polio eradication intensity is a variable that varies at the district level. Thus, it may indeed be the case that a higher programme intensity is directed towards *districts* where immunisation coverage is lower. Yet this would not translate directly into a higher exposure to the polio programme, which varies at the *child* level (depending on district, child age, and survey date). If this were the case, there would be a direct link between immunisation uptake and exposure to the polio pro-

[1]Table D.1 also suggests using immunisation indices with a low correlation to OPV coverage to address reverse causality concerns. Such robustness checks are discussed in Appendix C and largely replicate the presented findings. However, the inclusion of hepatitis B reduces the variation in the dependent variable and thus imposes limitations on the explanatory power of the results.

gramme on the child level. Table D.2 indicates that this is not the case: full immunisation attainment and polio round exposure are not correlated. This provides first indication that the presented results do *not* imply that children are exposed to more polio rounds simply because their immunisation coverage is low.

Table D.1. Correlation Between OPV and Immunisation Indices.

Immunisation Index (Incl. Vaccines)		OPV
1	BCG, DPT3, Measles	0.78*
2	BCG, DPT3, Measles, HepB	0.30*
3	BCG, DPT3, Measles, OPV	0.80*
4	BCG, DPT3, Measles, HepB, OPV	0.31*

Source: Own estimation.
Note. Only for Uttar Pradesh sample of children aged 10 to 30 months.
*p < 0.05.

Table D.2. Correlation Between Immunisation Index 1 and Exposure to Polio Rounds.

	Survey Round		
Age in Months	DLHS II	DLHS III	Combined
10	- 0.06	- 0.03	0.03
11	- 0.05	- 0.11*	0.06*
12	0.02	- 0.04	0.05
13	0.07*	0.06	0.10*
14	0.05	0.03	0.06*
15	0.01	0.00	0.10*
16	- 0.01	- 0.06	0.07*
17	- 0.05	- 0.07*	- 0.02
18	- 0.04	- 0.06*	0.02
19	- 0.07*	- 0.02	0.02
20	0.05	- 0.05	0.06*
21	- 0.09*	- 0.04	0.04
22	- 0.04	- 0.05	0.03
23	- 0.01	- 0.13*	0.01
24	- 0.04	- 0.09*	0.02
25	- 0.01	- 0.08*	0.03
26	- 0.03	- 0.14*	- 0.01
27	- 0.01	- 0.13*	- 0.01
28	- 0.10*	- 0.06	0.02
29	- 0.09*	- 0.14*	- 0.01
30	- 0.10*	- 0.14*	- 0.03
All Ages	0.04*	0.02*	0.06*

Source: Own estimation.
Note. Only for Uttar Pradesh sample of children aged 10 to 30 months.
*p < 0.05.

To provide further confidence that low immunisation coverage does not cause high exposure to polio eradication activities, sub-samples have been analysed that contain only districts with low immunisation coverage. If the argument of the reverse causality critique were correct, then the intensity of the polio eradication activities across this group of districts were *uniformly high* and no significant link between immunisation attainment and polio round exposure could be established. To explore this possibility, the bottom quintile of districts in terms of full immunisation coverage was selected for further analysis.

However, the definition of what constitutes such a group of districts is not clear and the selection may still be biased. Therefore, Table D.3 presents the results for eight different interpretations of the "bottom-quintile" group of districts (see Appendix B for detailed results). District-level immunisation coverage was estimated based on DLHS data, using the immunisation status as reported in the data set ("unweighted") and applying sample weights for a more representative immunisation coverage estimate on the district level ("weighted"). Four different methods of selecting the districts have been used. Firstly, district-level immunisation coverage was estimated using the pooled data set that includes immunisation data from both survey rounds. This group of districts has "bottom-quintile" immunisation coverage *across* both survey rounds. The second group comprises those districts that had "bottom-quintile" immunisation coverage during the DLHS II (the first survey round). In contrast, the third group includes districts that were ranked in the bottom quintile only in the DLHS III (the second survey round). The composition of these two groups differs because low-coverage districts during DLHS II may have improved and escaped the group of "bottom-quintile" districts by the next survey round, or some of the DLHS III "bottom-quintile" districts may not have been amongst the lowest-coverage districts during the DLHS II. The last group only includes those districts that have qualified as "bottom-quintile" in both DLHS II *and* in DLHS III (read "and" in a Boolean sense). Because this group is based on the intersection between the second and third set of districts, it comprises fewer districts than the former three groups (7 and 8 districts for the unweighted and weighted set of this group, respectively; the former groups comprise 14 districts each). All these eight sets of districts (four groups, each based on unweighted and weighted district immunisation coverage) include children across both survey rounds. The simple average (unweighted) immunisation coverage of the sampled children across these eight district groups ranges from 15.4% to 18.4%.

Table D.3 demonstrates that all interpretations of such low-performance districts exhibit a negative association between polio round exposure and full routine immunisation attainment, although age- and survey-specific effects tend to vary slightly. As the negative relationship is re-affirmed despite the selection of districts with low immunisation coverage, it appears likely that a high exposure to polio rounds *causes* low routine immunisation attainment.

Table D.3. Selected Model Results for Low Immunisation Coverage Districts.

Set of Districts	Bottom Quintile of Combined Data Set		Bottom Quintile of DLHS II		Bottom Quintile of DHLS III		Intersection of DLHS II and DLHS III Bottom Quintiles	
District Ranking	Unweighted	Weighted	Unweighted	Weighted	Unweighted	Weighted	Unweighted	Weighted
Restricted Model								
pol	-0.081***	-0.087***	-0.081***	-0.067**	-0.074**	-0.090***	-0.109***	-0.112**
Interaction Model (POLxAGE)								
pol	-0.006	0.018	-0.002	0.025	0.025	-0.014	-0.039	-0.028
POLxAGE	-0.003	-0.004**	-0.003*	-0.003*	-0.004*	-0.003*	-0.002	-0.003
Interaction Model (SURxPOLxAGE)								
pol	0.044	0.052	0.056	0.080	0.061	0.030	0.011	0.016
POLxAGE	-0.007***	-0.007**	-0.008***	-0.008***	-0.007**	-0.006**	-0.007*	-0.007*
SURxPOLxAGE	0.002**	0.002	0.002**	0.002**	0.002*	0.002*	0.002*	0.002
N	7,959	7,845	7,639	7,658	8,009	8,025	5,174	4,696

Source: Own estimation.

Notes. Coefficients reported. Estimating models for pooled data set using the respective ranking. Sample sizes vary owing to different sets of districts. Only main results displayed. Coefficient values of different models cannot be immediately compared due to varying samples.

*p < 0.05, **p < 0.01, ***p < 0.001.