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MASTER THESIS

Assessing Health Inequality: Childhood Immunization

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Supervisor: Associate Professor Cinzia Di Novi

GLODEP 2020

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Declaration

I, Kateryna Kravchenko, hereby declare that I am the author of this thesis and that I have not used any sources other than those listed as the references.

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Zásady pro vypracování

In the world's strive towards reaching the SDG 3 as ensuring healthy lives and promoting well-being for all at all ages, Ukraine is not only lagging in aiming the recommended threshold of 95% immunization coverage and showing substantially lower results in DTP3 and polio childhood vaccinations than the peer countries in the region but also is putting the risks on stake with recorded poliovirus and measles outbreaks during the last five years. The main goal of this research is to enable an understanding of factors associated with childhood immunization coverage in Ukraine in the spectrum of different dimensions of inequality. The study is structured around the following objectives: to present disaggregated childhood immunization data by such background characteristics as region and area (rural or urban) of residence, mother's education, sex of the child and household characteristics; to measure wealth- and education-related inequalities and geographical inequalities; to define the determinants underlying the childhood immunization coverage in Ukraine. The current studies are examining the childhood immunization inequality in Gavi-supported countries primarily. Ukraine stopped being supported by Gavi after 2008. Taking into account low national coverage during the recent ten years in Ukraine, assessing immunization within the dimensions of inequality alongside the country-specific context will help to deepen the understanding of its causes and lighten the path for future policy implications. The research will be organized on the descriptive analysis of disaggregated data on childhood immunization in Ukraine and followed by a concentration index analysis to capture the socioeconomic dimension of inequality and its graphical representation in concentration curves. The research will be based on the latest publicly available Multiple Indicator Cluster Survey performed in Ukraine in 2012. STATA 14 will be used as statistical software for data cleaning and analysis. The study might be used for further studies on health inequality in Ukraine and Eastern Partnership countries, particularly for capturing the trends upon the availability of new MICSs or DHSs.

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Arsenault, C. et al., 2017. Country-level Predictors of Vaccination Coverage and Inequalities in GAVI-supported Countries. *Vaccine,* Volume 35, pp. 2479-2488; WHO, UNICEF, 2019. *WHO and UNICEF estimates of national immunisation coverage, 2018.* s.l.:WHO, UNICEF; World Health Organization, 2013. *Handbook on Health Inequality Monitoring: with a special focus on low- and middle-income countries,* Geneva: World Health Organization.; World Health Organization, 2016. *State of Inequality: Childhood Immunization,* Geneva: World Health Organization.; World Health Organization, 2018. *Explorations of Inequality: Childhood Immunization,* Geneva: World Health Organization.; World Health Organization, 2018. *Global Vaccine Action Plan. Regional Reports on Progress towards GVAP-RVAP Goals. Annex to the GVAP Secretariat Annual Report 2018,* Geneva: World Health Organization.

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Abstract

Background: In the world's strive towards reaching the Sustainable Development Goal 3 (SDG3) as ensuring healthy lives and promoting well-being for all at all ages, Ukraine is not only lagging to reach recommended immunization coverage threshold and showing substantially lower results than the peer countries in the European region but also puts the risks on a stake with recorded poliovirus and measles cases during the last five years. However, there is limited knowledge of the factors underlying the immunization uptake in Ukraine. This research sheds light on the determinants of childhood vaccination and aims to measure and decompose socioeconomic inequalities in the receipt of the third dose of the diphtheria-tetanus-pertussis-containing vaccine (DTP3) in Ukraine.

Methods: The analysis was conducted with the use of data from the most recent publicly available Multiple Indicator Cluster Survey performed in Ukraine in 2012. The focal group of this research is children aged between 12 and 23 months. Immunization data was presented disaggregated by the background characteristics. Simple (ratio and difference) and complex (concentration index) measures of inequality were applied for assessing inequality in DTP3 immunization uptake. The Erreygers correction of concentration index was used to quantify and decompose socioeconomic inequalities accompanied by the concentration curve.

Results: The results suggest a pro-poor socioeconomic gradient in childhood immunization with the DTP3 vaccine in Ukraine measured by the concentration index (CI=-0.096). The decomposition analysis revealed that a substantial part of inequality was determined by household wealth. Mother's health beliefs and regional disparities were also contributing to inequality, while parental education was following the opposite direction.

Conclusion: Specific attention should be directed towards the Northern region while designing regional immunization policies. Tackling possible vaccine hesitancy, the focus should be made on such sources of healthcare information as TV and the Internet, which are negatively affecting the vaccination uptake. Since household economic status was the main factor contributing to pro-poor inequality in DTP3 immunization, further investigation might be needed to identify the reasons for lower vaccination coverage among the wealthier children, especially upon the availability of the new household surveys.

Keywords: Childhood immunization, Concentration index, Decomposition, Inequalities, DTP3 vaccination, Ukraine

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List of Abbreviations

BCG	Bacillus Calmette Guerin vaccine
cVDPV	Circulting vaccine-derived poliovirus
DHS	Demographic and Health Survey
DTP1	The first dose of diphtheria-tetanus-pertussis-containing vaccine
DTP3	The third dose of diphtheria-tetanus-pertussis-containing vaccine
GIVS	Global Immunization Vision and Strategy
GLM	Generalized Linear Model
GNI	Gross national income
GVAP	Global Vaccine Action Plan
HEAT Plus	Health Equity Assessment Toolkit Plus
HepB	Hepatitis B containing vaccine
HepB3	The third dose of Hepatitis B containing vaccine
Hib	Haemophilus influenzae type b containing vaccine
Hib3	The third dose of Haemophilus influenzae type b containing vaccine
MCV1	The first dose of measles-containing vaccine
MICS	Multiple Indicator Cluster Survey
MMR	Measles-mumps-rubella-containing vaccine
OLS	Ordinary Least Squares
Polio3	The third dose of poliomyelitis-containing vaccine
PSU	Primary Sampling Unit
SDG	Sustainable Development Goal
UNICEF	United Nations Children's Fund
VDPV	Vaccine-derived poliovirus
WHO	World Health Organization

Chapter 1. Introduction

1. Introduction

This chapter presents the background of the research and policy context in the first two sections. Sections 1.3 and 1.4 state the research purpose and relevance respectively, while Section 1.5 includes the limitations and research scope. The last section of this chapter outlines the structure of the thesis.

1.1. Background

More than two hundred years of research and development in the immunization field prove to be of great significance while coping with infectious diseases. Vaccination takes precedence even over the antibiotics in mortality reduction, stepping back only before the clean water as a simple means of disease prevention (Plotkin, Orenstein, & Offit, Vaccines, 2008). However, a specific requirement should be met to maintain immunization efficiency, known as the “herd” or “social” immunity: a large proportion of the immunized population will subsequently protect unvaccinated individuals by lowering the incidence of transmission. Whilst the ideal scenario of fully complete immunization coverage could barely ever be reached, the World Health Organization (WHO) sets 90% target for national coverage and 80% in every district for the vaccines in the national program as one of the goals in Global Vaccine Action Plan (GVAP) to be reached by 2020 (World Health Organization, 2013).

Looking back from the edge of the Decade of Vaccines 2011-2020 announced by WHO and following the traces of the GVAP roadmap, one can notice significant gaps between the goals set and results achieved. In the world’s strive towards reaching the Sustainable Development Goal 3 (SDG3) as ensuring healthy lives and promoting well-being for all at all ages, Ukraine is not only lagging to reach recommended coverage threshold and showing substantially lower results than the peer countries in the European region (World Health Organization, 2019) but also puts the risks on a stake with recorded poliovirus and measles cases during the last five years.

Albeit, labeling the results as a binary measure of “achieved” and “not achieved” does not represent the whole picture. Awareness of the existence of population groups falling short to be immunized will bring a deeper comprehension of the causes. Therefore, understanding the factors associated with immunization coverage broken down by different socioeconomic dimensions could help to uncover the missed opportunities for childhood vaccination, identify the underperforming subgroups, and lead to respective policy suggestions.

1.2. Immunization Policy Context

As stated in its position papers, the WHO suggests administering of ten vaccines to all children irrespectively of the region of residence (World Health Organization, n.d.). Following these recommendations, the Ukrainian routine immunization schedule includes all of them with the exception of pneumococcal and rotavirus vaccines (The Ministry of Health of Ukraine, 2018). For the better representation, the timeline of vaccination doses and boosters currently advanced in Ukraine with regard to the child's age is included in Table 1.

Noteworthy, the schedule of routine immunization in 2012 (Ministry of Health of Ukraine, 2011), as being a pivot for the analysis based on the availability of the latest Multiple Indicator Cluster Survey conducted in 2012 in Ukraine, slightly varied from the current one. The minor differences between two schedules were in the second dose of Hepatitis B vaccination introduced at the age of two months instead of one month, and revaccination against Tuberculosis at the age of seven being eliminated in 2018.

According to the Ministry of Health of Ukraine, the government provides free immunization against ten diseases listed in Table 1. In accordance with the schedule, children under 18 can get a free shot in the governmental medical centers and maternity hospitals. Regarding the adults, free vaccination is available against diphtheria and tetanus every ten years. For those associated with the risk group, such as military, Joint Forces Operation participants, healthcare workers, educators, and students, immunization against measles, rubella, and mumps is also provided free of charge. Due to the recent measles outbreak, grown-ups are eligible to get a free shot in case of the absence of the antibodies in the aftermath of serological tests (Ministry of Health of Ukraine, 2019).

As part of the state budget, the vaccines are purchased by UNICEF in six countries such as Belgium, France, Bulgaria, South Korea, India, and the USA, as claimed by the Ministry of Health of Ukraine (Ministry of Health of Ukraine, 2019). Since the access to immunization against above-stated diseases is free of charge for children, it could be addressed as a measure of health inequality in the spectrum of socioeconomic dimensions.

Table 1

Recommended Schedule of Routine Immunization Approved by the Ministry of Health of Ukraine

	1 day	3-5 days	2 months	4 months	6 months	12 months	18 months	6 years	14 years	Adults
Hepatitis B	1st dose		2nd dose		3rd dose					
Tuberculosis		1st dose								
Measles, rubella, mumps						1st dose		2nd dose		
Diphtheria, tetanus			1st dose	2nd dose	3rd dose		4th dose	5th dose		Every 10 years
Pertussis			1st dose	2nd dose	3rd dose		4th dose			
Poliomyelitis			1st dose	2nd dose	3rd dose		4th dose	5th dose	6th dose	
Hib infection			1st dose	2nd dose		3rd dose				

Note. Hib=Haemophilus influenzae type b containing vaccine. Adapted from “Calendar of prophylactic vaccinations”, Ministry of Health of Ukraine, 2018, retrieved from https://moz.gov.ua/article/immunization/kalendar-profilaktichnih-scheplen

1.3. Research Purpose

This thesis aims to enable understanding of factors associated with childhood immunization coverage in Ukraine by quantifying inequality in the form of the concentration index and its further decomposition. Furthermore, it highlights coverage of the main administered vaccines in the routine immunization schedule in Ukraine in the slice of the commonly used dimensions of inequality. On that account, this research leads to bridging the gap in awareness of discrepancies arising due to socioeconomic and demographic differences in immunization coverage apart from the geographic ones customarily examined within the national immunization monitoring programs.

The main research goal is to explore the determinants of the third dose of diphtheria-tetanus-pertussis containing vaccine coverage among children aged between 12 and 23 months in Ukraine.

This research is structured around the following specific objectives:

1. To present disaggregated childhood immunization data by such background characteristics as country region, area of residence, type of settlement, mother's education, child's gender and economic status of the household;
2. To measure socioeconomic inequality in immunization by applying the concentration index and graphically portraying it in the shape of the concentration curve;
3. To define the determinants underlying the vaccination receipt by the decomposition of the concentration index.

1.4. Relevance and Importance of the Research

The recent studies examining childhood immunization are directing their focus primarily towards the countries, supported by Gavi, the Vaccine Alliance (Arsenault, et al., 2017; World Health Organization, 2018; World Health Organization, 2016).

Ukraine stopped being supported by Gavi, the Vaccine Alliance after 2008 (Gavi The Vaccine Alliance, 2019), which shifted it to the back of the showcase of attention of international organizations. Albeit, persistent low national coverages during the recent ten years and vaccine-preventable diseases outbreaks in Ukraine set alarm bells ringing for the necessity of deeper examination of immunization issues. Assessing childhood immunization within the dimensions of inequality alongside the country-specific context will help to deepen the understanding of its causes and lighten the path for future policy implications.

The practical side of this research is anchored in the comparability of the results with the studies on the health inequality examining childhood immunization by means of simple measures of inequality (Hoissenpoor, et al., 2016), complex measures (Restrepo-Méndez, et al., 2016) and their further decomposition (Hajizadeh, 2019). Based on the data available in the Multiple Indicator Cluster Survey conducted in Ukraine in 2012, it opens the door for both within- and between-country inequality assessments as well possibility for further investigation of changes in inequality within the time upon the availability of recent household surveys.

1.5. Scope and Limitations

The scope of this research is determined based on the availability of comparable data on childhood immunization in Ukraine necessary for the calculation of immunization indicators and decomposition along with the commonly applied dimensions of inequality. The focal age group of children between 12 and 23 months as well as a choice of the third dose of the diphtheria-tetanus-pertussis vaccine (DTP3) for in-depth analysis is justified in Chapter 3. However, taking into account the administration of vaccines throughout different life stages, assessing inequality among the other population groups may be warranted.

The most recent comprehensive household survey in Ukraine was performed in 2012, containing the information on childhood immunization that could be further disaggregated by the background characteristics. As immunization coverages, together with parental healthcare perceptions, are not time-invariant, it is of great importance to maintain monitoring continuously and keep abreast of changes. Nevertheless, analysis of the abovementioned age cohort of 2012 can help to investigate potential causes of a bitter pill of outbreaks of measles and polio cases that occurred in the past five years in Ukraine and define the population groups that should be addressed to "close the immunization gap" proclaimed by the WHO (World Health Organization, 2016).

1.6. Outline of Chapters

This thesis is comprised of five chapters with accompanying appendices that reveal detailed results of the computation. Chapter 2 crosscuts the studies in epidemiology and health economics by highlighting the relevance of vaccination and providing a review of the literature on inequality in immunization. Chapter 3 presents an overview of the data sources and approaches to analysis. Chapter 4, as the main body of this thesis, reveals the main findings followed by the graphical representation of the results. Finally, chapter 5 concludes the results and provides relevant policy recommendations.

Chapter 2. Literature Review

2. Literature Review

This chapter will be structured around the literature on relevant vaccine administration and significance of the usage of several vaccine doses (Section 2.1), review of existing literature on the health inequality in immunization (Section 2.2) and the country-specific context in the specter of vaccination (Section 2.3) leading to literature gap this research aims to cover (Section 2.4).

2.1. Recommended Vaccine Administration and Dosage

On the global level, society enjoys the gains from immunization ranging from the apparent increase in life expectancy and reduction in childhood mortality from vaccine-preventable diseases to more subtle effects as fostering economic growth and easing the burden on the economy by enabling hospitals to work on other issues and receiving a consequent payback from investment directed to alternative areas (Ehreth, 2003). Immunization could indirectly impact women empowerment as a decline in childhood mortality leads to better family planning and an increase in intervals between pregnancies, which lowers the incidence of so-called "maternal depletion syndrome" as the time deficiency for postnatal recovery (Shearley, 1999). Only from 2000 to 2015, reduction in mortality rates from such diseases as measles, pneumonia, and malaria by more than 30% resulted in a substantial decrease of total under-five mortality rate (Liu, et al., 2016).

As a stepping-stone of the vaccination efficiency, herd immunity is believed to fall in a range between 83 and 94% (May & Silverman, 2002); however, it varies according to disease. Indicated in Table 2 coverages are necessary to cease disease transmission and, therefore, are crucial for the evaluation of vaccination program performance.

Table 2

Generally Accepted Herd Immunity Thresholds for Vaccine-Preventable Diseases

Disease	Herd immunity boundaries
Measles	92-95%
Mumps	75-86%
Rubella	83-86%
Diphtheria	83-86%
Pertussis	92-94%

(Continued on the next page)

Poliomyelitis	80-86%

Note. Adapted from "Vaccination", Vanderslott S., Dadonaite B., Roser M., 2020, retrieved from https://ourworldindata.org/vaccination

Apart from maintaining the herd immunity to reap the highest benefits from immunization, one should complete the recommended set of vaccine doses. Table 3 shows empirical evidence of vaccine efficacy with regard to the immunization schedule applied in Ukraine. The efficacy varies depending on certain conditions such as specific study case, vaccine producer or age, and weight of the child. However, the general trend traced in different studies shows the highest immunization performance in case of a complete vaccination schedule. Hence, it is important to capture multiple doses for evaluation of the country's immunization system performance.

Table 3

Review of Literature on Vaccine Efficacy

Vaccine/Disease	Doses/Boosters	Vaccine Efficacy	Studies (Author, Year)
Hepatitis B	1st dose	≈25%	(Schillie, et al., 2018)
	2nd dose	≈63%	(World Health Organization, 2017)
	3rd dose	≈95%	
Tuberculosis (BCG vaccine)	1 dose	> 80%	(Villarino, Huebner, Lanner, & Geiter, 1996) (World Health Organization, 2018)
Measles (MMR vaccine)	1st dose 2nd dose	84-94% 95-100%	(McLean, Fiebelkorn, Temte, & Wallace, 2013) (Uzicanin & Zimmerman, 2011) (World Health Organization, 2017)
Mumps (MMR vaccine)	1st dose 2nd dose	60-90% ≈94%	(McLean, Fiebelkorn, Temte, & Wallace, 2013) (World Health Organization, 2007)
Rubella (MMR vaccine)	1st dose 2nd dose	≈95% ≈99%	(McLean, Fiebelkorn, Temte, & Wallace, 2013)

(Continued on the next page)

Pertussis (DTP vaccine)	Complete vaccination	≈78%	(World Health Organization, 2015)
Diphtheria (DTP vaccine)	≥ 3 doses ≥ 5 doses	87-95.5% 98.4-99%	(Chen, et al., 2000) (World Health Organization, 2017)
Tetanus (DTP vaccine)	≥ 3 doses	≈100%	(World Health Organization, 2017)
Poliomyelitis	1st dose 3rd dose	≈50% >95%	(Prevots, Burr, Sutter, & Murphy, 2000) (World Health Organization, 2016)
Hib	Complete vaccination	95-100%	(Centers for Disease Control and Prevention, 2015)

Note. BCG=Bacillus Calmette–Guérin vaccine. MMR=Measles-mumps-rubella vaccine. DTP=Diphtheria-tetanus-pertussis vaccine. Hib=Haemophilus influenzae type b containing vaccine.

2.2. Health Equity: Factors Determining Incomplete or Delayed Immunization

2.2.1. Risk Dimensions

The studies on health inequality move along with the ones attempting to explain income inequalities. Thus, raising the issue of health inequalities in Great Britain in the previous century, Hart (1971) notices a geographical inconsistency in the medical care available, naming it as an "inverse care law." Building upon Hart's idea, further studies (Victora, Vaughan, Barros, Silva, & Tomasi, 2000) present a concept of "inverse equity hypothesis," starting from favoring the better-off and eventually narrowing the inequality gap. However, applying Kuznets inverted U-shape curve[1] (Kuznets, 1955) to inequalities in immunization with the hope that underprivileged will catch up with the span of time may not be the best policy decision, especially taking into account significantly higher initial vaccination coverage rates in case of Ukraine (World Health Organization, 2019).

Apart from geographical dimension, immunization inequalities could be assessed following described by Gwatkin (2007) catchy acronym PROGRESS standing for a place of residence, race, occupation, gender, religion, education, socioeconomic status, and social capital for each letter respectively. From the global perspective, SDG 17.18 calls to enhance the

[1] Kuznets advocates that with the development of the economy, inequality eventually decreases in a way of inverted U-shape relation between income per capita and inequality

availability of data broken down by income, gender, age, race, ethnicity, migration status, and other context-relevant features (United Nations, n.d.). However, some characteristics, including ethnicity, race, or religion, might have local specifications and, therefore, impose hardships on common measurement. The reasons impacting incomplete or delayed immunization could be grouped into several clusters, such as immunization systems, information and communication, parental attitude and behavior, and household characteristics (Centers for Disease Control and Prevention, 2009). Often they are (in)directly interlinked, giving an example of parental education and knowledge influencing general health beliefs and position towards immunization.

The WHO and Gavi, the Vaccine Alliance, use such inequality dimensions as characteristics of the child, mother, and household to assess a country's immunization performance (World Health Organization, 2018). Those attributes are included in Demographic and Health Surveys (DHS) and Multiple Indicator Cluster Surveys (MICS), which makes tracking possible for both cross-sectional and time-series analysis upon the availability of several surveys and ease country comparisons. Respectively, this research will employ a disaggregation of data by a child's sex, country region, area of residence, mother's education, and household socioeconomic status.

Even though some studies suggest assessing health inequalities in the slice of gender anytime possible (Whitehead & Dahlgren, 2006), generally studies do not consider it as an impactful factor in case of childhood immunization (Doherty, Walsh, & O'Neill, 2014; Gallagher, et al., 2016; World Health Organization, 2016; World Health Organization, 2018) as there are almost no or minor differences between vaccination coverages of boys and girls.

Education and wealth-related inequalities take commonplace in immunization. In a systematic literature review, Tauil, Sato & Waldman (2016) pointed out that low levels of the above-mentioned are usually associated with under-vaccination. However, such correlation might not always be true and should be carefully reviewed accounting for the country context, as shows Norway's case of a negative correlation between maternal education and HPV vaccination initiating (Feiring, et al., 2015).

2.2.2. Review of Inequality-Related Indicators

The necessity in looking deeper than just at the overall immunization coverage was particularly highlighted in the Global Immunization Vision and Strategy (GIVS) 2006-2015 as a common initiative of the WHO and UNICEF (World Health Organization, United Nations Children's Fund, 2005). Set in GIVS thresholds of 90% for national coverage and 80% for every district or equivalent administrative unit remained the same in the WHO's declaration of Decade of Vaccines in Global Vaccine Action Plan (World Health Organization, 2013). Following the trend, Gavi, the Vaccine Alliance quantified its Strategy for 2011-2020 into a dashboard of indicators embracing equity of coverage and mitigating possible barriers between and within 68 Gavi-supported countries keeping the same 90% and 80% approach (Gavi the Vaccine Alliance, 2016).

In the attempt to attain the higher equity in wealth, Gavi sets its indicator as no more than 19% and 16% difference in vaccination coverage between the lowest and the highest quantiles for 2015 and 2020, respectively (Gavi the Vaccine Alliance, n.d.). The WHO aligns with Gavi setting this target no higher than 20% for 75% of its member states by 2020 (World Health Organization, 2013). From the one side, bridging the gap between the richest and the poorest using those two poles of the spectrum as a matter of calculation can provide a quick and intuitively understandable view on existing wealth inequality. The other side of this approach conceals possibly occurring and underreported differences between or with the other 60% of the population.

The usage of multiple indicators varies depending on the component of the immunization program being evaluated. For the purpose of program output assessment, the coverage of the highest administered dose is being measured, while for the focus on equity components, the third dose of the diphtheria-tetanus-pertussis (DTP3) vaccine and the first dose of measles-containing vaccine (MCV1) are used (Sodha & Dietz, 2015). The reasons behind such choice are uncovering the capacity of the health system and access to immunization. Thereby, the first dose of the diphtheria-tetanus-pertussis (DTP1) vaccine could shed light on the availability of the health care services, whereas the third dose already considers the access of the household accounting for several visits to healthcare units. Similarly, MCV1, as one of the latest historically introduced vaccines, jointly with DTP3, represent the strengths of the country's healthcare system from the standpoint of immunization.

2.3. The State of Immunization in Ukraine

As a part of the European WHO region, Ukraine strikes out from the overall picture of the area with significantly lower immunization coverage rates during the previous decade (World Health Organization, 2019). On the way towards European Vaccination Action Plan goals (World Health Organization, 2014), Ukraine falls to meet almost half of them namely by not reaching 95%

of DTP3 vaccine coverage at the national level, reporting measles and rubella cases and questioning polio-free status due to occurred incidents in 2015 (Khetsuriani, et al., 2017).

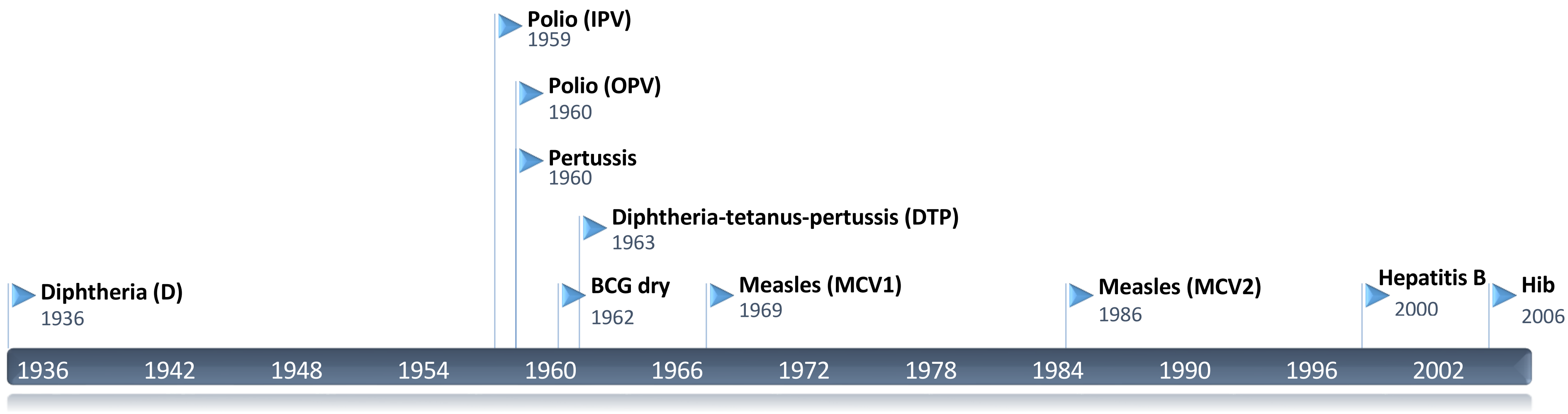
Reviewing historical events will provide a deeper understanding of underlying causes. Figure 1 captures the time dimension of the vaccine introduction in Ukraine. A major part of the vaccine currently used in the national immunization program was implemented during the Soviet Union time. Especially huge progress was made in 1960 and the subsequent years with the introduction of vaccines against poliomyelitis and combined vaccine against diphtheria, tetanus, and pertussis, and closing the decade with the measles-containing vaccine. Such efforts contributed to a sharp mortality decline from tetanus (40.5 fold), diphtheria (656.3 fold), pertussis (2016), and measles (1 061.1 fold) in the post-WWII time (Mokhort, Kovalchuk, Sokolovska, & Higgs, 2018). Hepatitis B (HepB) and Haemophilus influenzae type b (Hib) containing vaccine being globally in use since 1982 and early 1990s, respectively (World Health Organization, 2013; World Health Organization, 2017) were introduced in Ukraine in the early 21st century.

However, the recently reported incidences show alarming concerns about the spread of vaccine-preventable diseases in the country. Figure 2 illustrates a timeline of the major reported cases and vaccine-related events. The recent outbreak of measles in Ukraine after the considerable increase in measles occurrence in May 2017 showed rocketing numbers of 53 218 cases in 2018 as of 30 July 2019. Taking into account the total number of 84 462 cases ascertained in the European Region in 2018, Ukraine contributes to more than half of them with the incidence rate of around 1 209 per 1 million of the population. Apart from measles, there were 18 reported rubella cases in the first part of 2019 in Ukraine compared to 0 in the same period of 2018 (World Health Organization, 2019).

The outbreak of diphtheria in Ukraine with more than 5 000 and 1 300 cases recorded in 1995 and 1997 accordingly (World Health Organization, 2019) shows the importance of high immunization coverage leading to less than 50 cases reported from 2010 to 2018. In recent years, Ukraine shows substantially low levels of DTP3 coverage at the level of 23%, 19%, and 50% in 2015, 2016, and 2017-2018 years accordingly (World Health Organization, 2019).

Figure 1

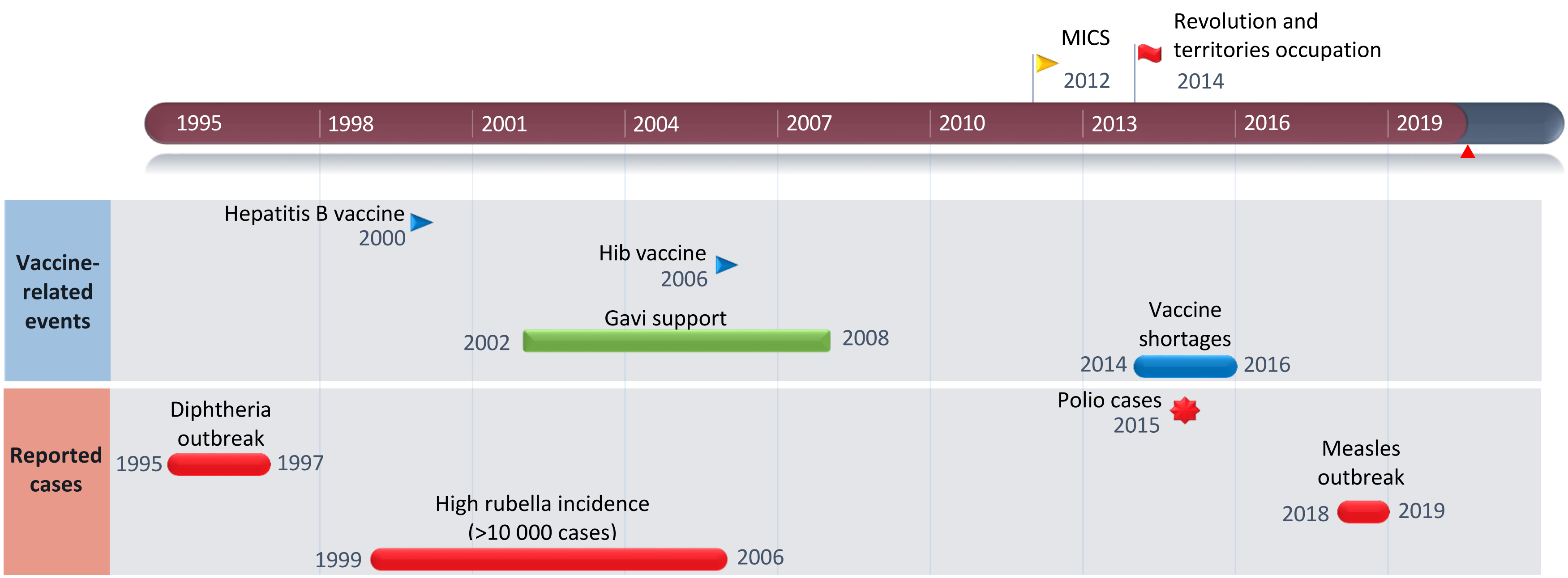
Timeline of Introduction of Vaccines into Routine Immunization Schedule in Ukraine



Note. Adapted from "Contribution of Vaccination to the Reduction of Infectious Mortality in Ukraine in the Second Half of the 20th and Early 21st Century: A Comparative Population-Based Study of the Dynamics and Structure of Infectious Mortality and Incidence" by Mokhort H., Kovalchuk A., Sokolovska O. & Higgs S., 2018.

Figure 2

Country-Specific Events Having an Impact on Immunization State in Ukraine



Note. Adapted from "Incidence time series for Ukraine (UKR)" by World Health Organization, 2019, retrieved from https://apps.who.int/immunization_monitoring/globalsummary/incidences?c=UKR

In 2002, the European Region was certified as a poliomyelitis free area with Ukraine having the last wild poliovirus isolated in 1993 and the last outbreak case in 1996 (World Health Organization, 2005). Ukraine maintained the high coverage of polio vaccination of overall six doses until 2009, facing the challenge of vaccine hesitancy later on after the failed mass immunization campaign against measles and rubella in 2008. In a short span of time, there were recorded 3 isolated detections of vaccine-derived poliovirus (VDPV) in 2014 and 2 polio cases of highly divergent circulating vaccine-derived poliovirus (cVDPV) in 2015 in Ukraine (Khetsuriani, et al., 2017).

Ukraine was receiving infection safety assistance or/and Hepatitis B vaccine support from Gavi the Vaccine Alliance over the span of six years and “graduated” from the Gavi-supported status in 2008 (Gavi the Vaccine Alliance, n.d.) due to ineligibility defined by the average GNI over the past three years (Gavi the Vaccine Alliance, n.d.). The same year coincided with the vaccine fright evolving after the death of a 17-year old Ukrainian adolescent preceded by the shot of the measles-containing vaccine (Lasco & Larson, 2020) and leading to significant decline in immunization coverage for almost all of the vaccines in the national immunization program for the next years.

Noteworthy circumstances to which Ukraine is exposed during the past six years due to the revolution in 2013-2014 and partial occupation of territories in 2014, may contribute to the inequality gap between the civilians in peaceful areas and those being at the highest risk in conflict surroundings. Akseer et al. (2020) point out that immunization coverage for the most disadvantaged children residing in the conflict countries was lower than the one recorded in countries that do not experience hostility. Ukraine is not an exception with a lower number of medical personnel working in affected by the conflict areas and a decline in immunization coverage (World Health Organization, 2014).

2.4. Existing Literature Gap

Despite the low national coverage and vaccine-preventable diseases outbreaks making Ukraine a particularly interesting research case, the recent studies did not examine immunization-related health inequality in-depth. Being a lower-middle income country, Ukraine falls out of the research focus on low- and middle-income countries, which is directed towards Gavi-supported countries primarily (Arsenault, et al., 2017; Restrepo-Méndez, et al., 2016; World Health Organization, 2016; World Health Organization, 2018)

In December 2019, the Countdown to 2030 initiative updated the list of countries, including Ukraine (Countdown to 2030, 2019), which was previously not considered as Countdown country in the latest published report (UNICEF, WHO, 2017). Countdown to 2030 as a descendent of Countdown to 2015 initiative aims to shed light on the world's success to achieve universal healthcare coverage and monitors inequalities in health on the basis of household surveys (Countdown to 2030, n.d.). Highlighting Ukraine as one of the focus countries with inequalities assessed based on the latest publicly available MICS (Countdown to 2030, 2019) is a huge step towards combating inequalities in health. However, there is a lot to be done to draw the whole picture.

Apart from quantifying inequality in a form of the concentration index, this research aims to reveal the determinants of socioeconomic inequality by decomposing it, which brings the case of Ukraine in line with the studies examining socioeconomic inequality in immunization (Doherty, Walsh, & O'Neill, 2014; Hajizadeh, 2019; Zhu, et al., 2018). Balancing between epidemiology and health economics, this study focuses on health inequalities in childhood immunization in Ukraine by assessing immunization within the dimensions of inequality alongside the country-specific context to help to deepen the understanding of its causes and lighten the path for future policy implications.

Chapter 3. Methodology

3. Methodology

This chapter examines the methodology used in the present research starting from the conceptual framework in Section 3.1, which presents the main approach, selection of independent and dependent variables as well as model specification. Section 3.2 examines the data description, while Section 3.3. presents the econometric framework of the research. The chapter is closed, showcasing the limitations and implementation of the methods using statistical software in Sections 3.4 and 3.5, respectively.

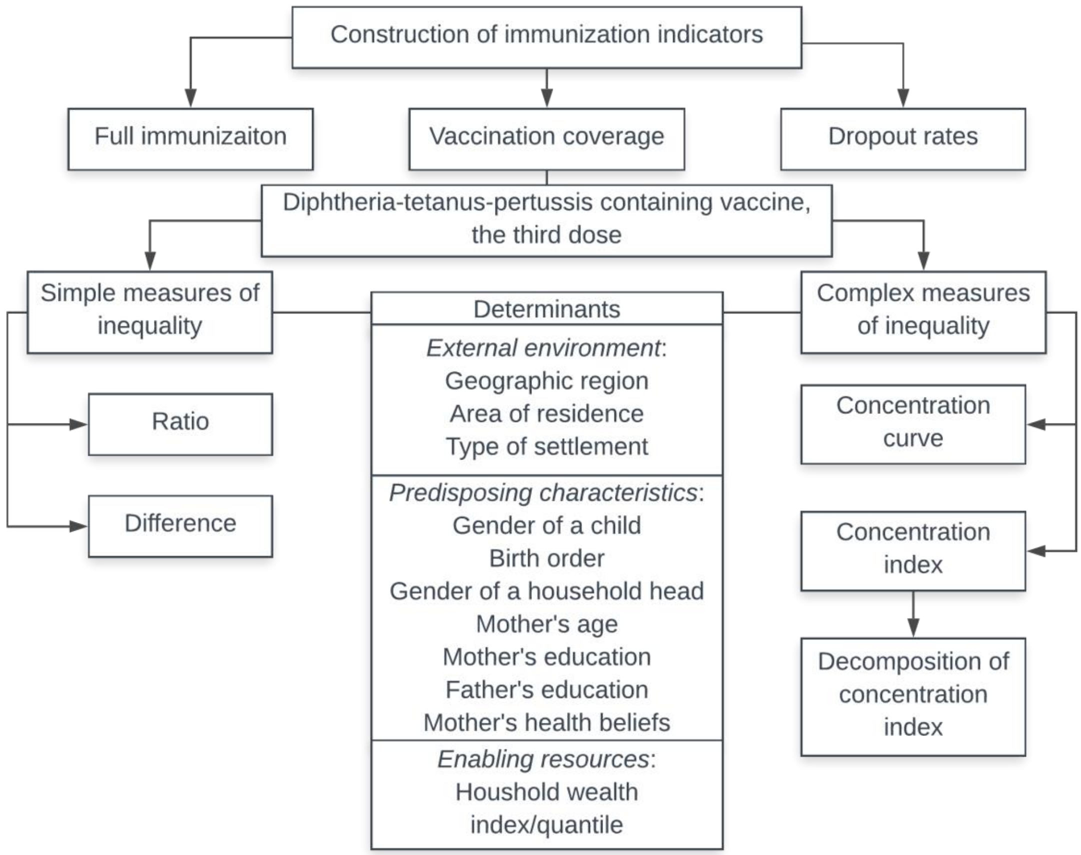
3.1. Conceptual Framework

Figure 3 provides an overview of the conceptual framework applied in the thesis according to the WHO's guide on health inequality monitoring (World Health Organization, 2013) and Andersen's Behavioral Health Model (Andersen, 1995). Standing on immunization indicators such as vaccination coverages and dropout rates as cornerstones of assessment, this research focuses on the further analysis of the third dose of the DTP3 coverage as the outcome variable, which is commonly used as an indicator of the performance of immunization program (Sodha & Dietz, 2015).

An examination of inequality in DTP3 immunization branches off into two directions of simple and complex measures of inequality. Determinants were chosen following Andersen's framework on factors that could be associated with access to healthcare and widely adopted in the studies examining health inequality (Herliana & Douiri, 2017; Titaley, Dibley, & Roberts, 2010). A detailed review of both types of measures, as well as underlying determinants, is presented in the sections below.

Figure 3

Conceptual Framework



Note. Author's elaboration based upon WHO Handbook on health inequality monitoring: with a special focus on low- and middle-income countries (2013) and Andersen's Behavioral Health Model (1995)

3.1.1. Construction of Immunization Indicators

To capture inequality in immunization, the WHO advises considering coverage indicators in the spectrum ranging from fully immunized children to so-called "left-outs" or "zero-dose children," who have not received vaccination at all (World Health Organization, 2019). Table 4 provides an outline of coverage indicators. Tracing the latter group can help to reveal potential problems of access to vaccination services or identify vaccine hesitancy. The DTP3 vaccine coverage is used as a proxy of full immunization for the first year of a child's life and deemed to represent the strength of the state health system. This measure, along with the measles-containing vaccine coverage, is repeatedly used for evaluation of the country's immunization program performance (Arsenault, et al., 2017; Tauil, Sato, & Waldman, 2016; Sodha & Dietz, 2015; World

Health Organization, 2018). The dropout rate, which could be placed in between two extremes of immunization range mentioned above, embraces the proportion of children being immunized with the first dose of vaccine, however, disregarded the following scheduled shots.

Table 4

Coverage Indicators and Vaccines Used for Estimation

Coverage indicators	Definition	Measures and vaccines used for estimation
Full immunization	Proportion of children that received all scheduled vaccination	BCG, DTP3, MCV, Polio3, HepB3, Hib3
Dropout rate	Proportion of children that have received the first dose of vaccination but not the third one according to the age	DTP1, DTP3, Polio1, Polio3, HepB1, HepB3, Hib1, Hib3
"Zero-dose"	Completely unvaccinated	No vaccine received

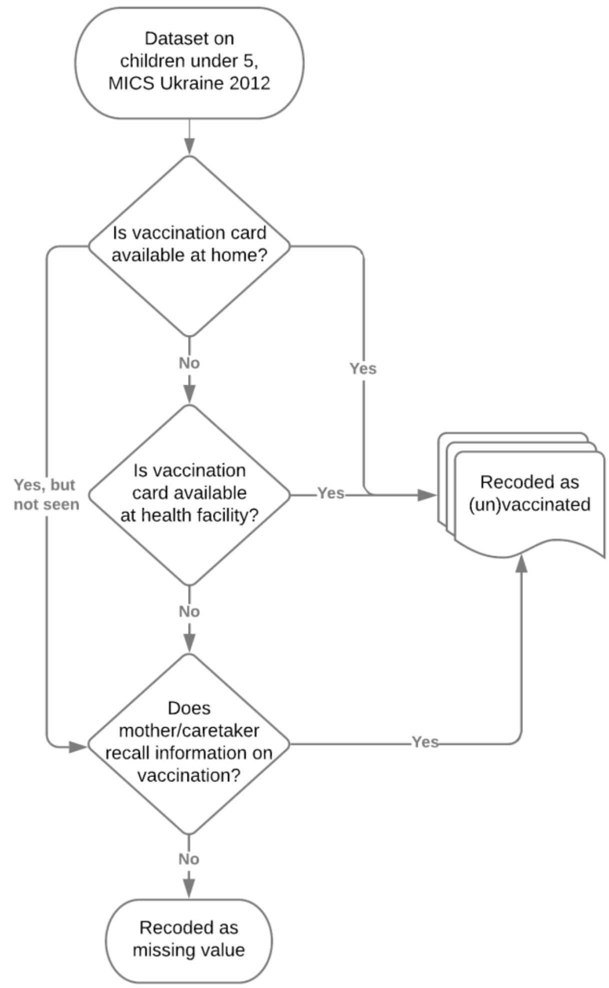
Note. DTP1=1st dose of diphtheria and tetanus toxoid with pertussis containing vaccine. DTP3=3rd dose of diphtheria and tetanus toxoid with pertussis containing vaccine. MCV=Measles containing vaccine. Polio3=3rd dose of poliomyelitis containing vaccine. HepB3=3rd dose of vaccine against Hepatitis B. Hib3=3rd dose of vaccine against Haemophilus influenzae type b.

Following the questionnaire accompanying the dataset (State Statistics Service and Ukrainian Center for Social Reforms, 2013) and codebook, the process of vaccination variables recoding was pursued in three stages shown in Figure 4: (1) checking for the note in the vaccination card at home, (2) checking for the record in the vaccination card at the health facility in case it was not available at home, (3) relying on the verbal history of vaccination by mother or caretaker if no vaccination card was seen or available. In case none of the three aforementioned options were available, the vaccination variable was recoded as missing.

The sample was restricted to observations of children aged between 12 and 23 months reflecting the age of receipt of the DTP3 vaccine and the first dose of the measles-containing vaccine as the markers of performance of the healthcare system, as well the other vaccines administered according to the Ukrainian schedule of routine immunization. A focal sample of the second-year old children makes this research available for collation with the results from the other studies in the field of inequality in childhood vaccination defining a coverage for the same age category (Hosseinpoor, et al., 2016).

Figure 4

Hierarchy of Evidence of Vaccination



Note. Author's elaboration

A binary variable was created for each vaccine type corresponding to 1 if the shot was received, and 0 otherwise. Afterward, dummy variables corresponding to dropout rates, full immunization, and zero-dose were generated. The dropout rate attained to 1, wherein the first shot was received aside from the third one administered according to the routine immunization schedule (Ministry of Health of Ukraine, 2018), and 0 otherwise. Full immunization was recoded as 1 in the event of having a complete number of vaccinations by 12 months on the contrary to the zero-dose variable being equal to 1 wherein none of the administered vaccine shots were carried out. The childhood immunization indicators were delineated as the percentage of children aged 12-23 months, which received a shot of the respective vaccine by the time the survey was conducted.

3.1.2. Inequality Dimensions, Dependent and Independent Variables

The WHO suggests a number of standard dimensions of inequality for analysis such as economic status of the household, educational level, area of residence, region, gender, and age (World Health Organization, 2017). These stratifiers are employed in this research for disaggregated data exploration and calculation of simple measures of inequality. Grounded in the Behavioral Health Model adapted by Andersen (1995), the selection of additional independent variables was based on the literature review and data available in the dataset. Table 5 summarizes determinants, which are also highlighted hereunder. The DTP3 immunization coverage was chosen and dependent variable taking a value of 1 if a child received vaccination shot, or 0 otherwise.

External environment factors

According to Andersen (1995), determinants that constitute the external environment include independent social and environmental factors. Representation of these dimensions in the model is given by the variables *region*, *areatype*, and *urban*. Hoissenpoor and Bergen (2016) stress the importance of data disaggregation by geographical region for future policy interventions, particularly in the case of the decentralized healthcare system. Tackling the most economically underprivileged might be a beneficial approach; however, not always feasible as this group might be dispersed throughout the country. Opening the door to policy actions with geographic consideration could be a possible solution. The household survey used in this research contains the data broken down by area of residence, such as urban or rural, type of area with regard to the size of the city or village, and five geographic regions of Ukraine.

Predisposing characteristics

Predisposing characteristics could be divided into three subgroups namely, demographic factors, social structure, and health beliefs. Demographic determinants are represented by the features determined in a way by the accidence of birth such as a gender of a child (*female*)[2], gender of household head (*head_sex*), birth order of the child (*birth_order*), mother's age (*m_age*). Even though inequality according to the child's sex is not prevalent in most of the countries, the WHO still highly recommends using this stratifier to monitor and prevent any emerging discrepancy

[2] Hereinafter, the name of the variable in the model is given in the brackets.

(World Health Organization, 2019). A presumption that higher birth order leads to a lower probability of vaccination holds due to the parents' negligence and overconfidence if the child is not a firstborn (Efendi, et al., 2019; Herliana & Douiri, 2017). Mother's age was grouped into age categories of 15-24 years, 25-29 years, and older than 30 years, with the second category being the most prevalent across the number of observations. This factor was not following a clear pattern in previous studies depending on the country-specific context leading either to lower vaccination among the children of older mothers (Zhu, et al., 2018), or of younger ones (Herliana & Douiri, 2017; Luman, McCauley, Shefer, & Chu, 2003) or had no significant effect on vaccination intake at all (Doherty, Walsh, & O'Neill, 2014). Since this thesis is focused on the children of the second year of life, the mother's age also reflects the mother's age at birth.

The social structure was constructed using the educational level of parents (*m_educ*, *f_educ*). The highest education level attained by a mother, father, or caregiver varies across countries and should be interpreted according to the country-specific context. While in some regions comparison of subgroups with no educational background and those having a higher academic degree is reasonable, in Eastern Europe, more rational would be juxtaposing secondary and higher education levels as schooling follows the path of almost universal post-primary education coverage (UNESCO, 2008). Therefore, the educational level of parents was constructed as a binary variable taking a value of 1 if a parent finished higher education or 0 in case of secondary education completion[3].

This research employed the data on the mother's source of trust concerning the health issues in the household as the proxy of health beliefs. The list of possible sources in the form of dummy variables is listed in Table 5. Andersen (1995) points out that considerations towards particular disease (such as diphtheria, tetanus, or pertussis) or health measure (such as immunization) might have a more substantial impact than general health beliefs. Due to the unavailability of the mother's attitude towards a specific type of immunization in the dataset, the mother's perception of the source of health information was used instead. Accordingly, some studies in inequality in immunization applied the data on mother's exposure to media representing health beliefs (Herliana & Douiri, 2017).

Enabling resources

[3] Including the observations for secondary education and lower due to the insufficient number of observations for the other categories.

Household economic status represents enabling resources that might influence childhood immunization. The wealth index, which stands for the economic status of the household, got popularity among researchers starting from the work of Filmer and Pritchett (2001) on educational enrollment in India and becoming a basis for assessing the health inequality in numerous following studies (Houweling, Kunst, & Mackenbach, 2003; Poirier, Grepin, & Grignon, 2019). Based on the wealth index, a survey sample could be divided into the subgroups from the poorest to the richest, typically into quantiles. Although the population sample could be split into smaller subgroups such as deciles, Victora and Ryman (2018) point out that this division could have limitations, namely in insufficient sample size per group. This thesis employs division into five wealth quantiles with the first and the fifth being the poorest and the richest, respectively (*wealth_quant*).

The model selection followed the steps of checking for collinearity between the independent variables, overall significance of the variables, and performing a link test to check whether the model was properly specified. Tests for the overall significance of variables and correlation were performed. As follows, variable *urban* was eliminated due to the issues of colinearity leaving a variable *areatype* categorized into a big city, small town, and solely rural area. No other variable was eliminated to avoid omitted variable bias.

Djemaï, Renard and Samson (2019) advocate for using a father's education in the model as its exclusion might lead to over-estimation of coefficients of mother's education. Such a case was observed while testing the model with and without the father's education. A certain caveat about including these two variables arose from the issue know as "selection into marriage", which shows that men and women with a similar level of education tend to live together or marry each other. The model improvement followed the steps of creating a number of dummy variables for the interaction of parental education[4]. Taking into account the results of the link test, including the father's education would result in better model specification. Therefore, the decision falls on choosing a model with both mother's and father's education despite a negative effect of the father's education coefficient on child immunization.

[4] Such as (1) at least one of the parents highly educated, (2) one of the parents highly educated and both parents highly educated, (3) combinations of parental education

Table 5

Description of Independent Variables

Characteristic	Type	Explanatory variable in the model
	External environment	
Subnational region	Categorical	South (0)
		North (1)
		West (2)
		Center (3)
		East (4), reference category
Place of residence	Dummy	Rural (0), reference category
		Urban (1)
Type of settlement	Categorical	Big city (1), reference category
		Small town (2)
		Rural (3)
	Predisposing characteristics	
	Demographic	
Child's sex	Dummy	Male (0), reference category
		Female (1)
Birth order	Categorical	First born child (0)
		Second or third child (1)
		Fourth child and more (2), reference category
Gender of household head	Dummy	Male (0), reference category
		Female (1)
Mother's age	Categorical	15-24 (0)
		25-29 (1)
		30> (2), reference category

(Continued on the next page)

Social structure		
Mother's educational level	Dummy	Secondary and lower (0), reference category
		Higher (1)
Father's educational level	Dummy	Secondary and lower (0), reference category
		Higher (1)
Health beliefs		
TV	Dummy	No (0), reference category
		Yes (1)
Newspaper	Dummy	No (0), reference category
		Yes (1)
Friends and relatives	Dummy	No (0), reference category
		Yes (1)
Magazines	Dummy	No (0), reference category
		Yes (1)
Radio	Dummy	No (0), reference category
		Yes (1)
Health worker	Dummy	No (0), reference category
		Yes (1)
Internet	Dummy	No (0), reference category
		Yes (1)
Pharmacy	Dummy	No (0), reference category
		Yes (1)
Books	Dummy	No (0), reference category
		Yes (1)
No trust concerning health issues	Dummy	No (0), reference category
		Yes (1)
Other sources	Dummy	No (0), reference category
		Yes (1)

(Continued on the next page)

Enabling resources		
Household wealth	Categorical	Quantile 1 (1)
		Quantile 2 (2)
		Quantile 3 (3)
		Quantile 4 (4)
		Quantile 5 (5), reference category

3.2. Data Description

3.2.1. Data Source Mapping

A broad view of immunization data could be found in large-scale surveys or administrative data sources. High-income countries usually rely on the latter ones for analysis, as the data collected is not only considered as accurate but also representative and stratified (Victora & Ryman, 2018) leaving no need to perform DHS or MICS used for the same purposes in low- and middle-income countries (UNICEF, n.d.; USAID, n.d.). As opposed to the household surveys that are conducted frequently following designed questionnaires, administrative data is collected instantly by the health workers. However, during the recent decade, the quality of data reported by the national government of Ukraine was questioned and estimated again by WHO and UNICEF due to potential mistakes or biases such as reporting higher coverages of DTP3 immunization than DTP1 or reporting the sudden changes in coverage (WHO, UNICEF, 2019).

Known for its "golden standard" methodology (Hancioglu & Arnold, 2013), starting from the second round, MICS includes disaggregated data by geographic region, area of residence, educational level of the mother, and a wealth index calculated based on the items possessed by the household (UNICEF, 2015). Such a structure makes equity analysis possible both within a country and between the countries undertaking a survey.

According to the World Bank classification, Ukraine belongs to lower-middle-income countries (World Bank, n.d.) and hosted several rounds of household surveys since 2000. Given a number of data sources available and stated in Table 6, the choice falls on the latest MICS carried out in Ukraine in 2012, which includes data both on childhood immunization and socioeconomic characteristics of the household on which this research focuses. Whereas preceding household surveys are lacking information on childhood immunization, the study is framed around the dataset from 2012, excluding the time comparison yet making it a stepping stone for future analysis when more recent data on immunization disaggregated by socioeconomic dimensions will be available.

Despite the lengthy period since the survey was conducted, subsequent analysis of the data collected can bridge the gaps in understanding the causes of further detrimental events that took place in Ukraine during the recent years, such as measles outbreak and recorded cases of poliomyelitis.

Table 6

List of Data Sources Available for Ukraine

Data source type	Data source title	Year(s) of data collection	Notes
Household survey	MICS	2012	Data on childhood immunization and socioeconomic characteristics
Household survey	DHS	2007	No data on childhood immunization
Household survey	MICS	2005	No data on childhood immunization
Household survey	MICS	2000	No data on childhood immunization
Administrative data	Official government estimate	Annually	Data on immunization coverage not disaggregated by socioeconomic dimensions

Note. Adapted from "Surveys", UNICEF, 2020, retrieved from http://mics.unicef.org/surveys; "Survey Search", USAID, 2020, retrieved from https://dhsprogram.com/What-We-Do/survey-search.cfm?pgtype=main&SrvyTp=country&ctry_id=230.

3.2.2. Sample Design Consideration

MICS in Ukraine in 2012 employed a two-stage cluster sample design by initial selection of the primary sampling units (PSUs) within each stratum and followed by a selection of households among the ones listed in PSUs. Stratification process was based on the five geographical regions (North, South, West, East, and Center) and level of urbanization within the region (big city, town and rural area) leading to the construction of 15 strata (State Statistics Service and Ukrainian Center for Social Reforms, 2013).

The restricted sample of children aged between 12 and 23 months includes 855 observations with assigned sampling weights. Stratification, cluster design, and sampling or probability weights were taken into account to obtain unbiased estimates and correct standard errors (O'Donnel, Doorslaer, Wagstaff, & Lindelow, 2008).

3.3. Econometric Framework

3.3.1. Simple Measures of Inequality

Analysis based on the simple measures proves its name by providing intuitive and easily interpretable outcomes. Absolute and relative health inequalities as simple measures are represented by difference and ratio of the mean values of each subgroup accordingly. Further calculation and representation of simple measures hinge upon the inequality dimension and groups' order type. While some subgroups such as wealth quantiles or educational level could be naturally ranked, the same logic of order would not be applicable for area of residence or country region. The latter subgroups, called non-ordered, present a subject to a certain complexity in identifying the utmost values upon which difference and ratio should be calculated.

To avoid the construction of an excessive number of indicators, the WHO underlines the importance of measurement of both difference and ratio, relying on the most extreme results as the reference groups (World Health Organization, 2013). An ideal scenario of using pairwise comparison appears in case of the existence of only two subgroups, such as the sex of the child, making the analysis the most comprehensible. The columns revealing the difference and ratio calculation in Table 7 were framed appertaining to stated WHO recommendations and reference subgroups defined on the basis of household surveys (World Health Organization, 2018).

Table 7

Population Subgroup Categorization with Corresponding Simple Measures for Childhood Immunization Monitoring in Ukraine

Dimension of inequality	Subgroup categorization	Difference calculation	Ratio calculation
Household economic status	Quantile 1 (poorest) Quantile 2	Quantile 5 – Quantile 1	Quantile 5/Quantile 1

(Continued on the next page)

	Quantile 3 Quantile 4 Quantile 5 (richest)		
Mother's education	Secondary Higher	Higher education – Secondary education	Higher education/Secondary education
Area of residence	Urban Rural	Urban – Rural	Urban/Rural
Type of area	Big city[5] Small town[6] Rural	Area with the highest coverage – Area with the lowest coverage	Area with the highest coverage/Area with the lowest coverage
Country region	North[7] West[8] Center[9] East[10] South[11]	Region with the highest coverage – Region with the lowest coverage	Region with the highest coverage/Region with the lowest coverage
Sex of child	Female Male	Female – Male	Female/Male

3.3.2. Complex Measures of Inequality: Concentration Index

Employment of complex measures of inequality in line with simple ones complements the picture of the state of health inequality and helps to overcome limitations arising from solely pairwise comparison by capturing data on the whole population. After the introduction by Kakwani (1980) and Wagstaff, Doorslaer & Paci (1989) concentration index gained popularity among the researchers exploring health inequalities in different dimensions (Barros, et al., 2012; Gwatkin, 2007) including immunization (Doherty, Walsh, & O'Neill, 2014; Hajizadeh, 2018; World Health

[5] With a population of 100 000 and more
[6] With a population of less than 100 000
[7] Including Kyiv city and Kyiv, Zhytomyr, Sumy and Chernihiv regions
[8] Including Ivano-Frankivsk, Khmelnytskyy, Chernivtsi, Lviv, Rivne, Ternopil, Volyn and Zakarpattia regions
[9] Including Cherkassy, Poltava, Kirovograd and Vinnytsya regions
[10] Including Dnipropetrovsk, Donetsk, Zaporizhzhya, Luhansk and Kharkiv regions
[11] Including Crimean AR, Sevastopol city and Odesa, Mykolaiv and Kherson regions

Organization, 2018). The grassroots of the concept of concentration index take us back to the beginning of the 20th century when the famous works of Lorenz (1905) and Gini (1912) allowed plotting inequality over the two dimensions of population share and income (or wealth) distribution and quantifying it. However, the Gini coefficient[12] and its graphical representation in the form of the Lorenz curve[13] differ from their descendants, namely concentration index and concentration curve, in a number of given characteristics.

Firstly, the Gini index takes into consideration only income (or wealth) distribution on the contrary to the concentration index, which captures the correlation between both socioeconomic status and health. Such an add-in makes the latter one a bivariate indicator by attaching the "socio" part to previously solely economic measure. For that reason, concentration index can fall into a range of [-1; 1] (or [-100;100]), while the Gini coefficient limits its range to only positive values of [0;1] (or [0;100]). In both cases, greater absolute numbers represent higher inequality, while equality will be indicated as zero. Albeit such a scenario is highly implausible, the values of -1 and 1 represent a situation when the most (dis)advantaged person possesses a "monopolistic power" over the volume of the health variable available in the society.

Clearly, bivariate nature affects a concentration curve, which is tightly connected to the concentration index as the Lorenz curve to the Gini index. The Lorenz curve takes the space below the line of so-called "perfect equality" corresponding to a 45° line between the axes of the cumulative share of population and cumulative share of income. Conversely, the concentration curve can be nested both below and above the "perfect equality" line when the concentration index is positive and negative, respectively.

The sign of the concentration index (as well the position of the concentration curve) is an important component of the indicator that allows tracking the direction of the inequality. By relying on the socioeconomic status, the concentration index reveals which part of the population is the most severely affected by inequality. In other words, it shows whether the inequality is pro-rich (favoring the better-off) or pro-poor (favoring the most economically inferior).

Nevertheless, the intricate kind of the concentration index restricts from univocal defining an inequality type by merely looking at the sign unless the health variable is clearly delineated.

[12] Gini coefficient, or Gini index, is a measurement of inequality within the income distribution, and falls in range of 0 and 1 (or 100%) in case of perfect equality or maximum inequality respectively

[13] Lorenz curve is a graphical representation of cumulative share of population and cumulative share of income (or wealth), where perfect equality corresponds to 45° line between the two axes

When interpreting the results, one should draw a distinction between health attainments ("good health") such as access to healthcare, child or adult health, and shortfalls ("ill health") such as child morbidity, malnutrition, or smoking. Table 8 illustrates the direction of inequality according to the type of health variable and sign of the concentration index. Immunization benefits society by sustaining a herd immunity and is considered as a proxy of good health. Therefore, it follows the pattern of health attainment favoring the most well-off in case of positive sign of the concertation index, and the least ones otherwise.

Table 8

Direction of Inequality Determined by the Sign of Concentration Index and the Nature of the Health Variable

	Health attainments	**Health shortfalls**
Positive sign of CI	Pro-rich	Pro-poor
Negative sign of CI	Pro-poor	Pro-rich

Note. CI=Concentration Index.

The concentration index could be obtained as the area between the line of "perfect equality" and the concentration curve multiplied by two or as a covariance between the health variable and the fractional rank of an individual according to the socioeconomic status (Wagstaff, Paci, & Doorslaer, 1991):

$$C = \frac{2cov(r,h)}{\mu}, \quad (1)$$

where r stands for the rank of the living standards, h corresponds to the health variable, and μ represents the mean level of health.

The straightforward computation of the index was also proposed by Kakwani, Wagstaff and Doorslaer (1997):

$$C = \frac{2}{n*\mu}\sum_{i=1}^{n} y_i R_i - 1, \quad (2)$$

where y_i represents the health determinant of the i^{th} individual, R_i is the fractional rank of the i^{th} individual, and μ stands for the mean level of health. The individuals are ranked from 1 to n, where the first one is the most disadvantaged person, and n^{th} person is the most advantaged. Taking into account that individuals may receive the same ranking number as they might be compared equally, the fractional ranking should be used. The same ranking number would correspond in that case to the mean of the ranking place they would have received under the ordinary ranking.

However, considering the nature of the health variable and the level of its measurement, further studies (Wagstaff, 2005; Erreygers, 2009) started questioning the approach used initially and proposed certain corrections. Wagstaff (2005) draws attention to the point that the concentration index could be normalized, dividing it by the upper bound once the health variable is binary. In his paper, Wagstaff notes that with the higher means of the health variable, the values of the concentration index fall into a narrower range and incline to zero. From the first view, it might seem that the higher means (in the case of immunization, higher coverage rates) indicate lower inequality since the concentration index decreases. However, that appears to be not an invariable case, as proven by examples from developing countries studied over time and mentioned in the same study. Wagstaff's correction is a subject of particular interest for assessing inequality in immunization as the variable studied takes a value of 1 if a child received a vaccination shot or 0 otherwise. Wagstaff-normalized concentration index (W) could be computed following the formula:

$$W = \frac{\mu(b-a)}{(b-\mu)(\mu-a)} * CI \tag{3}$$

where a and b represent the lower and upper bounds respectively, μ stands for a mean of the health variable and CI to the concentration index calculated as (2).

However, Erreygers (2009) points out that the approach undertaken by Wagstaff (2005) does not satisfy all the desirable conditions such as transfer[14], mirror[15], level independence[16] and cardinality[17], which is considered in Erreygers' correction:

$$E = \frac{4\mu}{(b-a)} CI \tag{4}$$

with the same description of the variables as in case of Wagstaff's correction (3). Moreover, Erreygers highlights that such to some extent simple transformation of the concentration index transforms the indicator to both absolute and realtive measure of inequality.

[14] A transfer from the richer or poorer parts of the society should be indicated in a change of the index
[15] The indices of inequality of health attainments and shortfalls should be "mirrored" with the opposite sign
[16] An equal change in the health variable for the whole population should not affect the concentration index
[17] A linear transformation of the health variable should not affect the concentration index irrespectively of the level of measurement of it

Kjellsson and Gerdtham (2013) emphasize on the interpretability of the index proposed by Erreygers and stress the importance of index selection for inequality assessment comparing three abovementioned indicators. Taking into account the features of the variety of given alterations of concentration index and a kind of health variable studied such as childhood immunization, the choice in this research falls on the Erreygers correction. An additional convenience of the indicator is adduced by the possibility of its further decomposition presented in the next subchapter.

3.3.3. Decomposition of Concentration Index

One of the apparent advantages of the concentration index lies not only on the surface as quantifying inequality in health but also in allowing digging into deeper layers of what could serve as a potential cause of it. A decomposition of the concentration index can reveal how much of the socioeconomic health inequality is determined by each of the individual factors.

Wagstaff, Doorslaer, and Watanabe (2003) pointed out that decomposition might be useful for answering three questions: to calculate the drivers of health inequality at a specific time, to assess discrepancies in inequality and changes over time, and to evaluate the effects of particular programs and policies. While the primary focus of this research is spanning around the first question, the latter two might present an interest for further studies upon the availability of the data or policy interventions. The one-dimensional approach of decomposition, named after its authors as WDW, consists of two elements such as deterministic and residual:

$$GC = 2\sum_{j=1}^{k} \beta_j Cov(x_j, d) + 2Cov(\varepsilon, d), \quad (5)$$

where Generalized Concentration Index (GC) is explained by a sum of k contributions of each explanatory variable x_j corresponding to the deterministic part, and a residual component $Cov(\varepsilon, d)$. β_j represents the coefficients.

Taking into account Erreyger's (2009) correction for bounded (binary) variables, the new decomposition formula would be slightly reshaped:

$$E(h) = 4\left[\sum_{j=1}^{k} \beta_j GC_j(x_j) + GC(\varepsilon)\right], \quad (6)$$

where $GC_j(x_j)$ is a generalized concentration index of explanatory variable x_j and $GC(\varepsilon)$ stands for the same of an error term.

If the residual part of the concentration index is deemed to be unexplained by the model, the deterministic part of it could be compiled as a weighted sum of the inequality, namely concentration indices of the k regressors, in each of the explanatory variable x_j with the weights qualified as health elasticities of the determinants. The latter could be depicted as:

$$\widehat{\eta_J} \equiv \frac{\widehat{\beta_J}\bar{x}_j}{\mu}, \quad (7)$$

where $\widehat{\beta_J}$ represents partial effects, $\bar{x}_j$ and μ stand for mean of each determinant and outcome variable respectively. The contribution of each variable could be obtained by multiplying elasticity by the concentration index of each regressor, which in percentage terms could be expressed if divided by the overall concentration index.

Ordinary Least Squares (OLS) was initially used for decomposition of concentration index (Wagstaff, van Doorslaer, & Watanabe, 2003). However, taking into account the binary nature of the outcome variable such as receipt of the DTP3 vaccine, the Generalized Linear Model (GLM) is preferred over OLS. Reflection of the binomial distribution followed by the outcome variable and ability to maintain the link function between independent and dependent variables make GLM an appropriate model of choice for the decomposition of concentration index (Yiengprugsawan, Lim, Carmichael, Dear, & Sleigh, 2010). This research will employ GLM with a binomial link and logit family for calculation of the partial effects.

According to van Doorslaer and Koolman (2004), total inequality could be divided into so-called “potentially avoidable” and “unavoidable.” One can receive conceivably preventable inequality by subtracting expected inequality by inescapable characteristics corresponding to demographics such as sex or age from the concentration index.

As van Doorslaer and Koolman leave it up to a researcher to decide, which background characteristics to be attributed as demographic, this study will employ child’s gender and birth order, household head gender and mother’s age to the category of “unavoidable”, which in a manner are determined by the accidence of birth. The age of a child was not included as only the category of children between 12 and 23 months are considered. Contrarily, the educational level of mother and household wealth level presented as quantiles allocated to the category of non-demographic attributes. Such an approach of demographic standardization will allow controlling for the confounding effect of “unpreventable” characteristics.

Demographic standardization could be performed using an indirect approach described in details by O’Donnel, Doorslaer, Wagstaff, and Lindelow (2008), where indirectly standardized health could be obtained following the formula:

$$\widehat{h_i^{IS}} = h_i - \widehat{h_i^x} + \bar{h}, \tag{8}$$

where $\widehat{h_i^x}$ are predicted or expected demographic values of the health indicator, h_i and $\bar{h}$ stand for the actual health, and overall sample mean respectively.

As the primary measure of interest of this research is the concentration index, decomposition of it into the need and non-need contributions and subsequent subtraction of the need part, will lead to the same result of the need-standardized concentration index (van Doorslaer & Koolman, 2004).

Therefore, the independent variables used for the decomposition of the concentration index were divided into four groups such as income-related, need factors representing aspects determined by the accidence of birth, non-need factors, and health beliefs. Based on such division, equation (6) could be rewritten in a way:

$$E(h) = 4[\sum_w \beta_w \overline{x_w} CI(x)_w + \sum_n \beta_n \overline{x_n} CI(x)_n + \sum_{nn} \beta_{nn} \overline{x_{nn}} CI(x)_{nn} + \sum_m \beta_m \overline{x_m} CI(x)_m + GC(\varepsilon)], \tag{9}$$

where $\overline{x_w}$, $\overline{x_n}$, $\overline{x_{nn}}$, $\overline{x_m}$ represent means of wealth (x_w); need factors such as sex of the child and household head, child's birth order, and mother's age (x_n); non-need factors such as parental education, region, and type of settlement (x_{nn}); health beliefs represented by the mother's trust in different sources of information (x_m) respectively. $CI(x)_w$, $CI(x)_n$, $CI(x)_{nn}$, and $CI(x)_m$ are their concentration indices, and $GC(\varepsilon)$ is the residual term. Such decomposition allows having a closer look at the groups of determinants influencing the socioeconomic inequality in childhood immunization quantified by the concentration index itself.

3.4. Limitations

There are several limitations to this thesis. Firstly, in case of the absence of the vaccination card at home and at the health facility, or if it was not seen by the interviewer, the estimation was based on the mother's verbal history of vaccination. Even though previous studies confirmed rather a high accuracy of parental recall (AbdelSalam & Sokal, 2004), it was also observed that its validity depends on the type of vaccine (Saurez, Simpson, & Smith, 1997). Complete exclusion of the mother's responses would result in possible under-/overestimation of coverage. Since an ideal scenario of relying solely on the written records from all the respondents to avoid a potential parental recall bias was matter-of-factly not possible, the assessment was made with a combination of both the abovementioned sources of information on child's immunization.

Secondly, due to the unavailability of more recent household surveys in Ukraine, this research relied on the data collected in 2012. In order to track progress towards achievement of SDGs, it is recommended to conduct DHSs or MICSs with a frequency of four times every ten years (Global Partnership for Sustainable Development Data, 2016), while the WHO and UNICEF recommend performing surveys every five years pointing it out while revising estimates of country's immunization coverage (WHO, UNICEF, 2019). As this research is cross-sectional, future studies might collect longitudinal data to examine the determinants and changes in inequality over time.

Thirdly, accounting for the education of both of the parents results in assessing only the households with full families (Djemaï, Renard, & Samson, 2019). That leads to elimination of the observations from households without fathers.

3.5. Stata Implementation

Data cleaning and analysis were performed using Stata v.14. The sample was restricted to observations of children aged between 12 and 23 months and variables accounting for relevant child and household characteristics. With regard to survey design, *svyset* command was employed with subsequent application of *svy* prefix. *Svyset* command produces Taylor linearized standard errors, which allow accounting for the weights, clustering, and stratification used in the complex design of the survey (StataCorp, 2013). As the final weights in the dataset were normalized[18] (State Statistics Service and Ukrainian Center for Social Reforms, 2013), they cannot be used for estimation of the population totals. However, normed weights will lead to the same results as non-normalized while obtaining the point estimates essential for this research purposes such as means and proportions, and conduction regression analysis (Brogan, 2005).

The command *conindex* was used for the purposes of estimation of the concentration index (O'Donnell, O'Neill, Ourti, & Walsh, 2016). This research applied *erreygers* option to account for the binary nature of the dependent variable, and *svy* prefix to include the survey design. The concentration curve was plotted using the command *glcurve* with option *lorenz* for setting ordinate Y as a cumulative proportion of the health variable alternatively to cumulative means used by default, and *twoway* (O'Donnel, Doorslaer, Wagstaff, & Lindelow, 2008).

[18] So that the weighted number of respondents would be equal to unweighted sample number that have responded to the questionnaire

The subsequent decomposition of the concentration index followed several stages. Firstly, the GLM was applied using the command *glm* along with the options *family(binomial) link(logit)* to obtain the marginal effects of independent variables (Yiengprugsawan, Lim, Carmichael, Dear, & Sleigh, 2010). The model specification was checked using the command *linktest*, while collinearity issues were checked with the command *collin* giving both variance inflation factor and tolerance.

Afterward, concentration indices, elasticities, and contributions of each of the regressors were obtained using a set of commands within the loop *foreach*. Primarily to calculations of concentration indices of independent variables, the categorical variables were transformed into binary for application of Erreygers correction by creating dummy variables for each group of the categorical variable.

Chapter 4. Results and Discussion

4. Results and Discussion

This chapter starts with the descriptive statistics (Section 4.1) and proceeds with the simple measures of inequality, such as ratio and difference (Section 4.2). The next section is dedicated to complex measures of inequality, namely concentration index calculation and its graphical representation in the form of the concentration curve (Section 4.3.1) followed by the decomposition results (Section 4.3.2).

4.1. Descriptive Statistics

This section showcases estimates for immunization coverage drawn from data from MICS 2012 for Ukraine for children aged 12-23 months across different inequality dimensions suchlike wealth quantile, mother’s education, sex of the child, area of residence, type of settlement and country region. As a rule of thumb, a graphical portrayal of data conveys the message in a concise and straightforward manner leading to the employment of several pictorial options and data visualization tools in this research. A closer examination of the estimates of immunization coverage and dropout rates broken down by equity stratifiers including standard error and 95% confidence intervals are presented in Appendices 1 and 2. Appendix 3 exhibits the estimates of DTP3 coverage over the determinants used included in the decomposition of concentration index.

The recent studies (Assaf & Pullum, 2016; Barros, et al., 2020; Costa, Weber, Darmstadt, Abdalla, & Victora, 2020) employ equiplots to visually represent disaggregated data as a further descendant of simple measures of inequality (International Center for Equity in Health, n.d.). As a figure of horizontal dots presenting coverage by subgroups across the inequality dimensions, equiplot displays inequalities as distances between the points. Simplicity and clarity in the elucidation of the results make equiplot a depiction of choice when it comes to an illustration of disaggregated data on childhood immunization (World Health Organization, 2016). This study will use equiplots as a graphical representation of vaccination coverage and dropout rates by such equity stratifiers as wealth index quantiles, educational level of the mother, and child’s gender.

Design choice for the area of residence and type of settlement falls for bar graphs with depicted confidence intervals. Each bar represents an estimated vaccination coverage (dropout rate) for the subgroup, a closer comparison of which builds a composite picture of territorial disparities. For each vaccine type, two bar graphs are plotted closely for correspondence not only between urban and rural areas but also including division of the latter subgroup into a small town and rural area per se. For the purpose of a depiction of regional disparities, the bar graphs with the national average line were used. The gap between the national average line and graph bars shows how much each of the regions is falling behind or getting ahead the country mean.

When approaching descriptive analysis, all the graphical representation was made using the Equiplot creator developed by the International Center for Equity in Health (International Center for Equity in Health, n.d.) and Health Equity Assessment Toolkit Plus (HEAT Plus) developed by the WHO (World Health Organization, n.d.). Both tools require primary disaggregation of data, conducted in this research by means of Stata v. 14.

Overall estimation

The obtained estimates show disparities between vaccination coverages according to the vaccine type (Appendix 1). Full immunization corresponds to the completed vaccination schedule appropriate for the age of focus of this research, namely BCG, DTP3, MMR, HepB3, and Hib3. The national average estimate for children aged 12-23 months for full immunization is considerably low, attaining to the level of just 5.8% (*95% CI* 3.5% to 8%). The proportion of completely unvaccinated children or so-called zero-dose, which have not received any vaccination shot, is estimated at 0.6% (*95% CI* 0.1% to 1%).

The dropout rates can reveal the other side of the immunization story (Appendix 2), embracing a proportion of children that have received the first shot but not the last one appropriate for their age. Since this research focuses on the sample of children in their second year of life, the third dose of DTP, Polio, HepB, and Hib vaccines were considered for dropout rate estimation. By convention, it is much easier to receive the first doses of vaccination, as the following ones require a multiple number of visits to the health facility.

The highest dropout rate as well, as the lowest coverage among the other vaccine types, is exhibited by the Hib vaccine. Taking into account that the third dose of the Hib vaccine is administered at the age of 12 months, the lower coverage rates (15.9% with *95% CI* 11.3% to 20.6%) could indicate a possible delay in vaccination as the focus sample is aged between 12 and 23 months. The same statement is also applicable for the first dose of MMR vaccine (national coverage 50.2% with *95% CI* 44.6% to 55.9%), which requires a health facility visit at the same age.

Household economic status

Figures 5 and 6 represent the estimated vaccination coverage of children aged between 12 and 23 months by vaccine type and the wealth quantile as a proxy for household economic status. Figure 7 depicts dropout rates for the vaccine types, which are repeatedly administered by the time a child reaches one year.

Figure 5

Immunization Coverage with BCG, DTP3, Polio3 and Measles-Containing Vaccine by Wealth Quantile

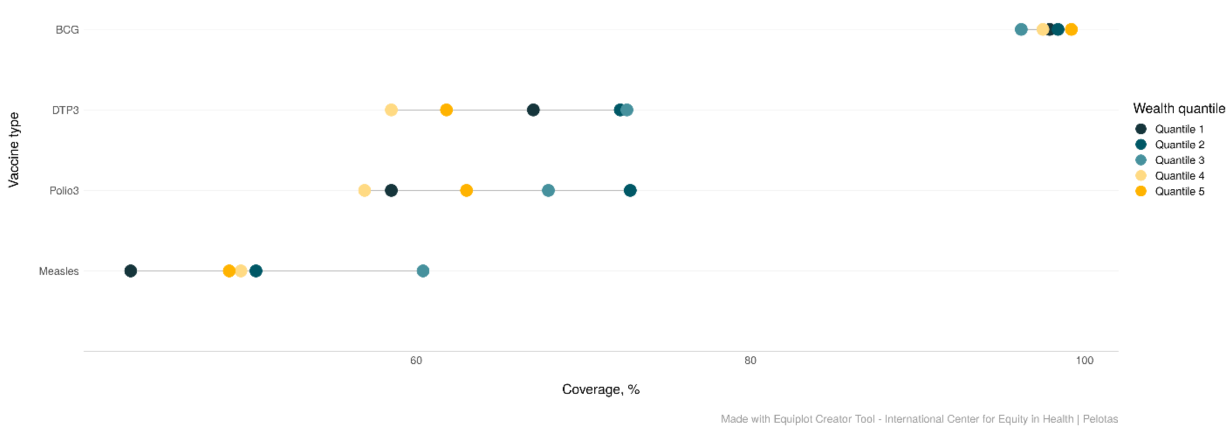


Figure 6

Full Immunization Coverage and Coverage with Hib3 and HepB3 Containing Vaccine by Wealth Quantile

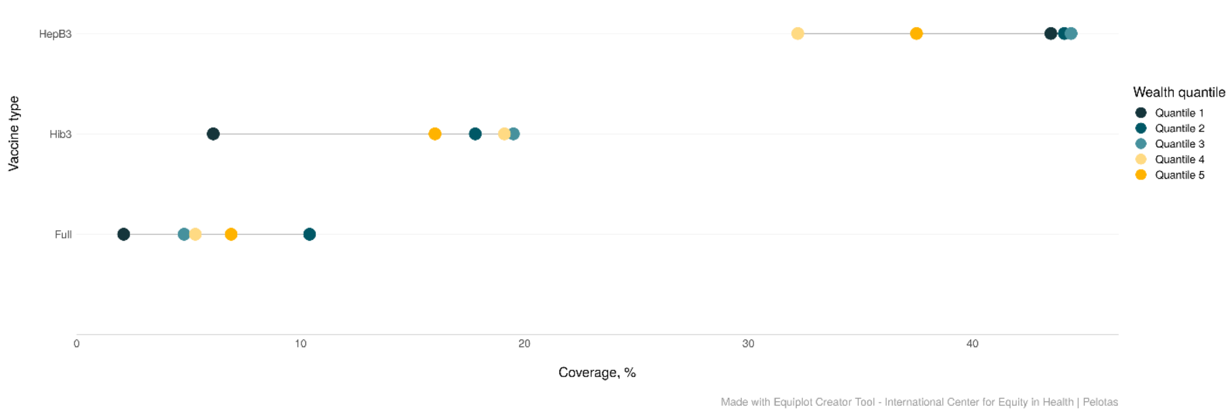
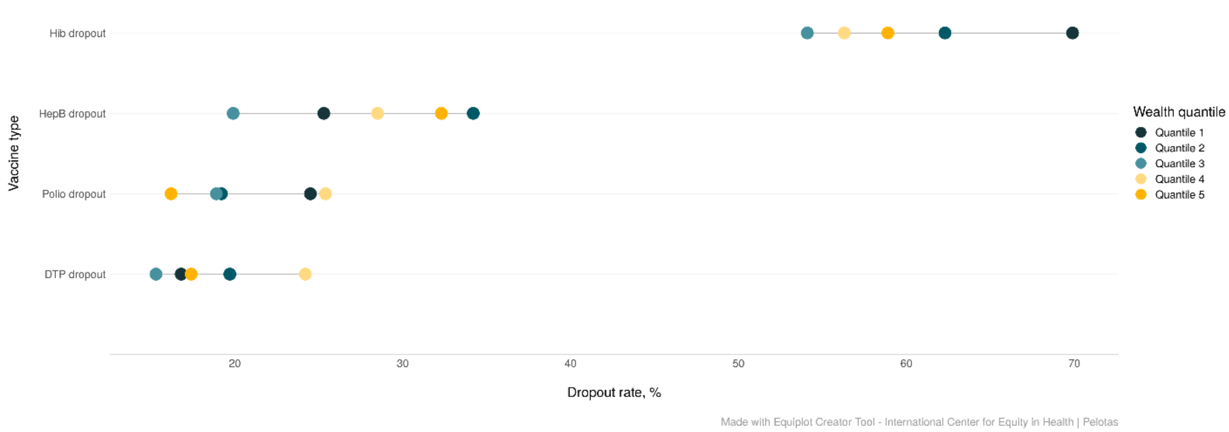


Figure 7

Dropout Rates of the DTP, Polio, Hib and HepB Containing Vaccine by Wealth Quantile



Both total and in the slice of dimensions of inequality, the highest estimated vaccination coverage is with BCG vaccine accounting to 97.9% overall and with insignificant differences across wealth index quantiles. Considerably lower coverage estimates are obtained for Hib3 and HepB containing vaccines as ones introduced the most recently in the routine immunization schedule in Ukraine in 2006 and 2000 respectively.

The results show no general trend towards the single wealth group outstripping in high vaccination coverage. Contrarily to believe that the low socioeconomic status leads to insufficient vaccination coverage (Tauil, Sato, & Waldman, 2016), no clear direction of the association between both of the abovementioned was observed as it varies depending on the type of immunization. With the exception of BCG, Polio3, and full immunization, the third quantile was showing one of the highest coverages and one of the lowest dropout rates.

Educational level of mother

Figures 8 and 9 compare the estimates for the vaccination coverage disaggregated by the level of mother's education, while Figure 10 adds on the estimates of the dropout rates. Apart from BCG coverage and HepB dropout rate showing the minor differences between subgroups, the presence of the gap between secondary and higher education is evident and ranges from 3.2% (full immunization coverage) to 20.4% (Hib dropout rate).

Figure 8

Immunization Coverage with BCG, DTP3, Polio3 and Measles-Containing Vaccine by Mother's Level of Education.

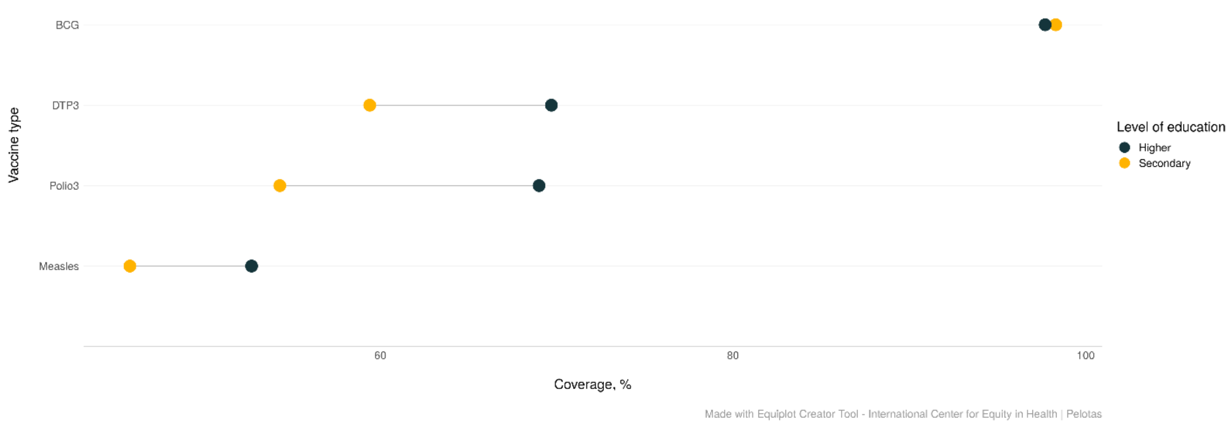


Figure 9

Full Immunization Coverage and Coverage with Hib3 and HepB3 Containing Vaccine by Mother's Level of Education

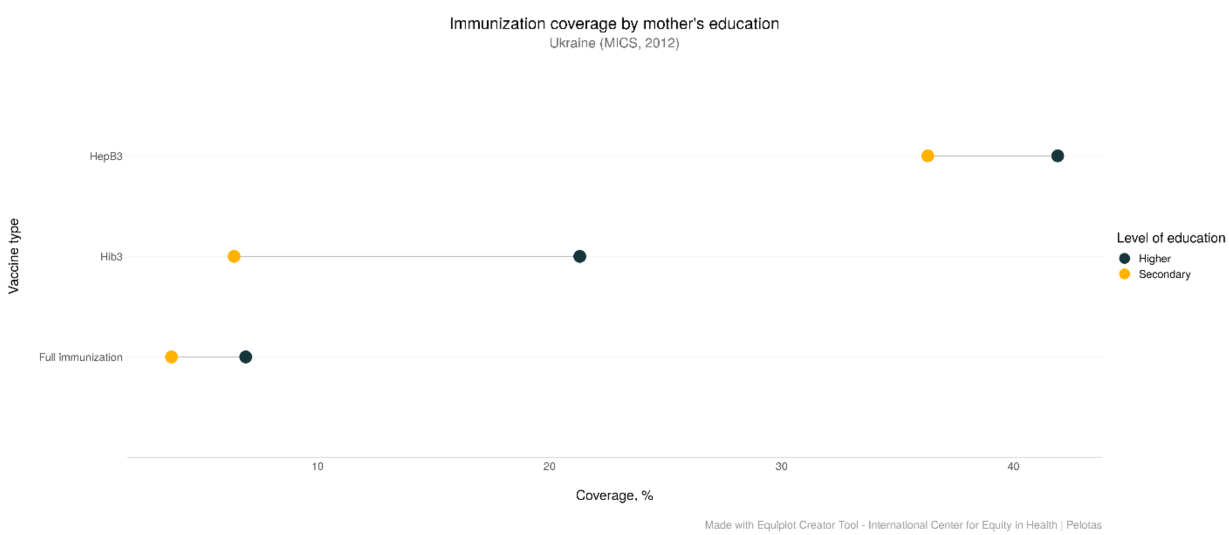
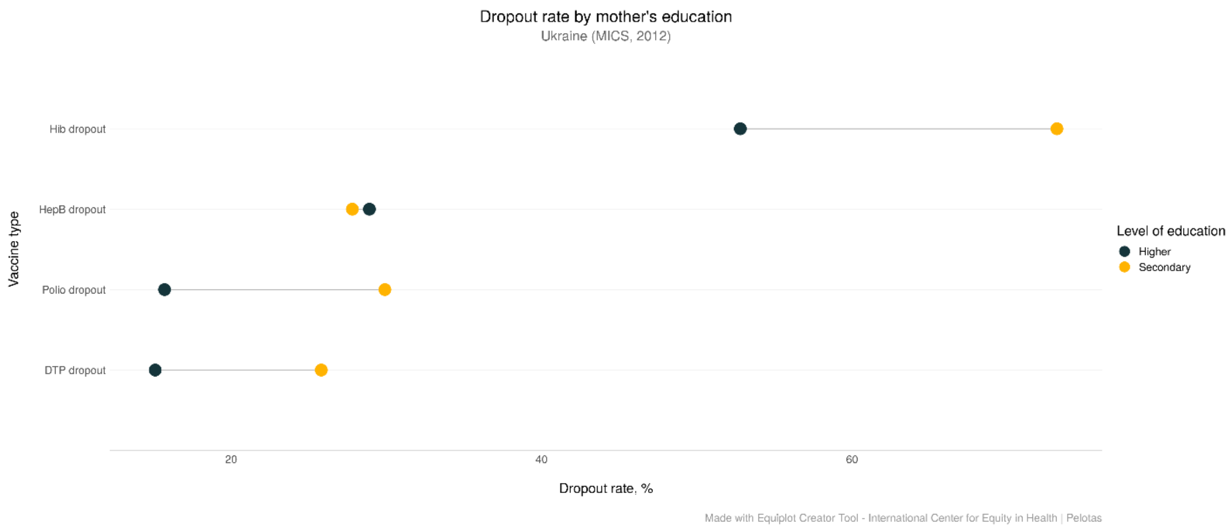


Figure 10

Dropout Rates of DTP, Polio, HepB and Hib Containing Vaccine by Mother's Level of Education



Child's gender

Although the difference between estimates of vaccination coverage existed between girls and boys (Figures 11-13), it substantially varied with regard to the vaccination type and without the exhibition a clear trend. The measles-containing vaccine is administered as a part of the combined vaccine against mumps and rubella (MMR). According to the WHO (World Health Organization, 2007), 20% of male mumps patients develop orchitis[19], which later might be associated with impaired fertility. Fostered by the impact of media, awareness of this complication is well spread in Ukraine. Thus, it may urge parents of boys to make MMR vaccination in time resulting in differences according to gender in vaccination coverage.

[19] Inflammation of one or both testicles

Figure 11

Immunization Coverage with BCG, DTP3, Polio3 and Measles-Containing Vaccine by Child's Sex

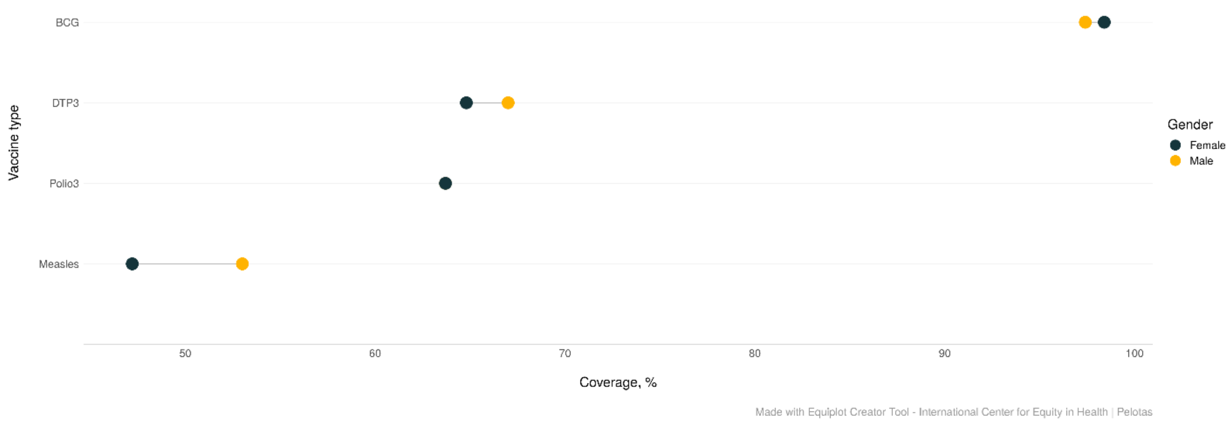


Figure 12

Full Immunization Coverage and Coverage with Hib3 and HepB3 Containing Vaccine by Child's Sex

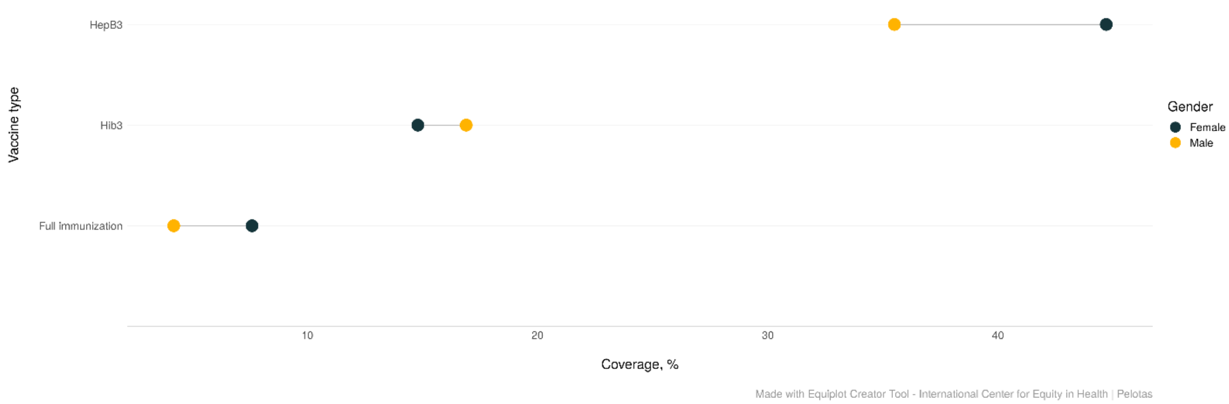
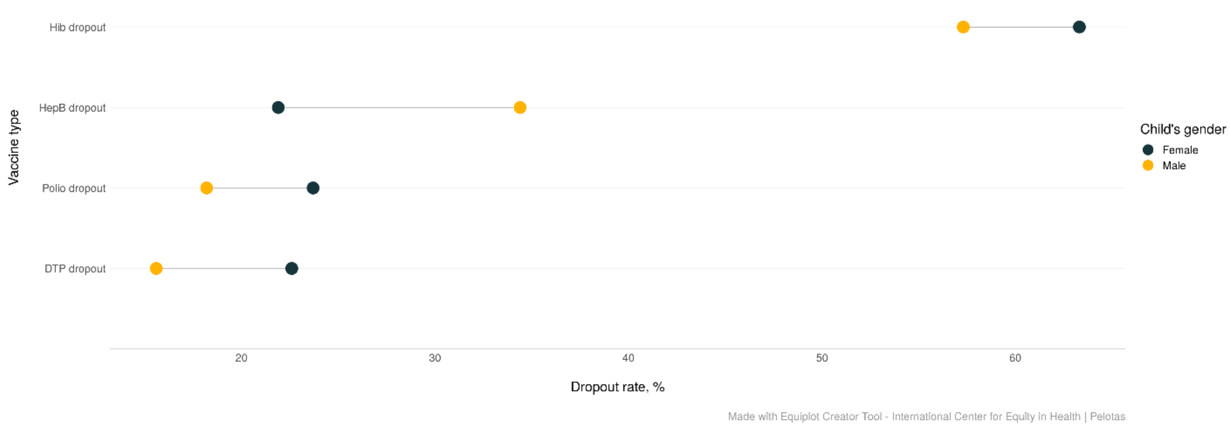


Figure 13

Dropout Rates of the DTP, Polio, HepB and Hib Containing Vaccine by Child's Sex



Area of residence and type of settlement

Accounting for the minor differences between rural and urban areas and type of settlement for BCG, DTP3, and Polio3 vaccinations (Appendix 1), Figures 14 and 15 display vaccination coverage and dropout rates for those vaccines, where territorial disparities were more noticeable. Measles vaccination coverage shows insignificant differences between urban and rural areas (51.1% and 49.6% respectively). However, a closer look at the breakdown of the rural area into small towns and the rural countryside itself disclose higher coverage for the former over the latter (57.8% and 41% respectively). Hib3 vaccination coverage follows a similar trend. Regarding the dropout rates, the highest estimates were obtained for rural areas for Hib and HepB containing vaccines, as the ones introduced most recently. Contrarily, countryside areas were showing the lowest dropout estimates comparing to small and big cities for the vaccines rooted in the vaccination schedule of Ukraine since the Soviet Union times such as DTP and Polio.

Figure 14

Immunization Coverage with Hip3, HepB3 and Measles-Containing Vaccine by Area of Residence and Type of Settlement

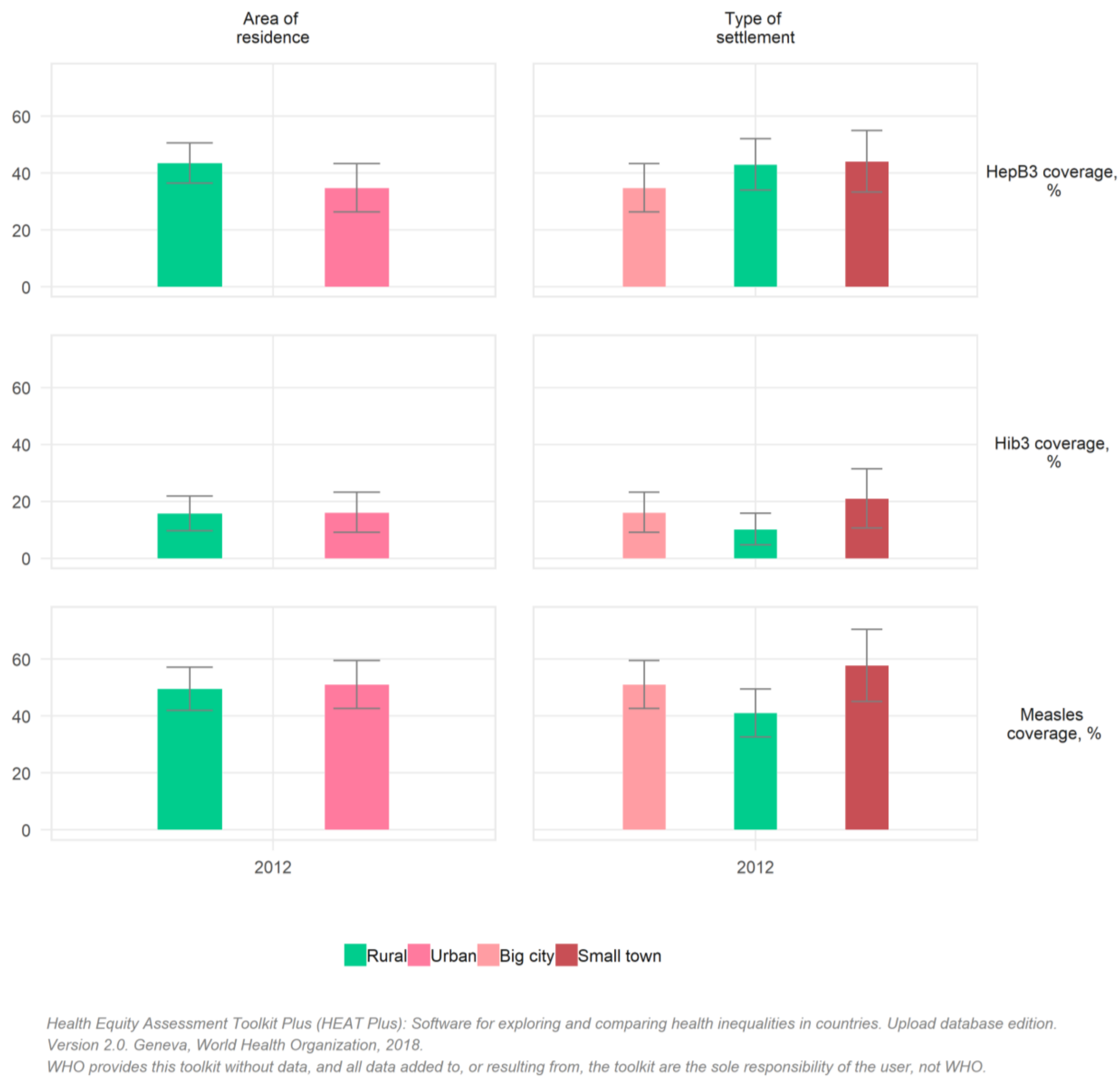


Figure 15

Dropout Rates of the DTP, HepB, Hib and Polio Containing Vaccine by Area of Residence and Type of Settlement

Health Equity Assessment Toolkit Plus (HEAT Plus): Software for exploring and comparing health inequalities in countries. Upload database edition. Version 2.0. Geneva, World Health Organization, 2018.
WHO provides this toolkit without data, and all data added to, or resulting from, the toolkit are the sole responsibility of the user, not WHO.

Country region

Figures 16-19 portray the estimates for vaccination coverage and dropout rates by the type of vaccine and five country regions. With the exception of BCG vaccine, the Southern region is performing the best in vaccination coverage significantly surpassing the country's average with the Eastern region being the second best. Northern and Center regions constitute the lowest immunization coverages and the highest dropout rates for DTP and Polio vaccines.

Figure 16

Immunization Coverage with BCG, DTP3 and Polio3 Containing Vaccine by Region

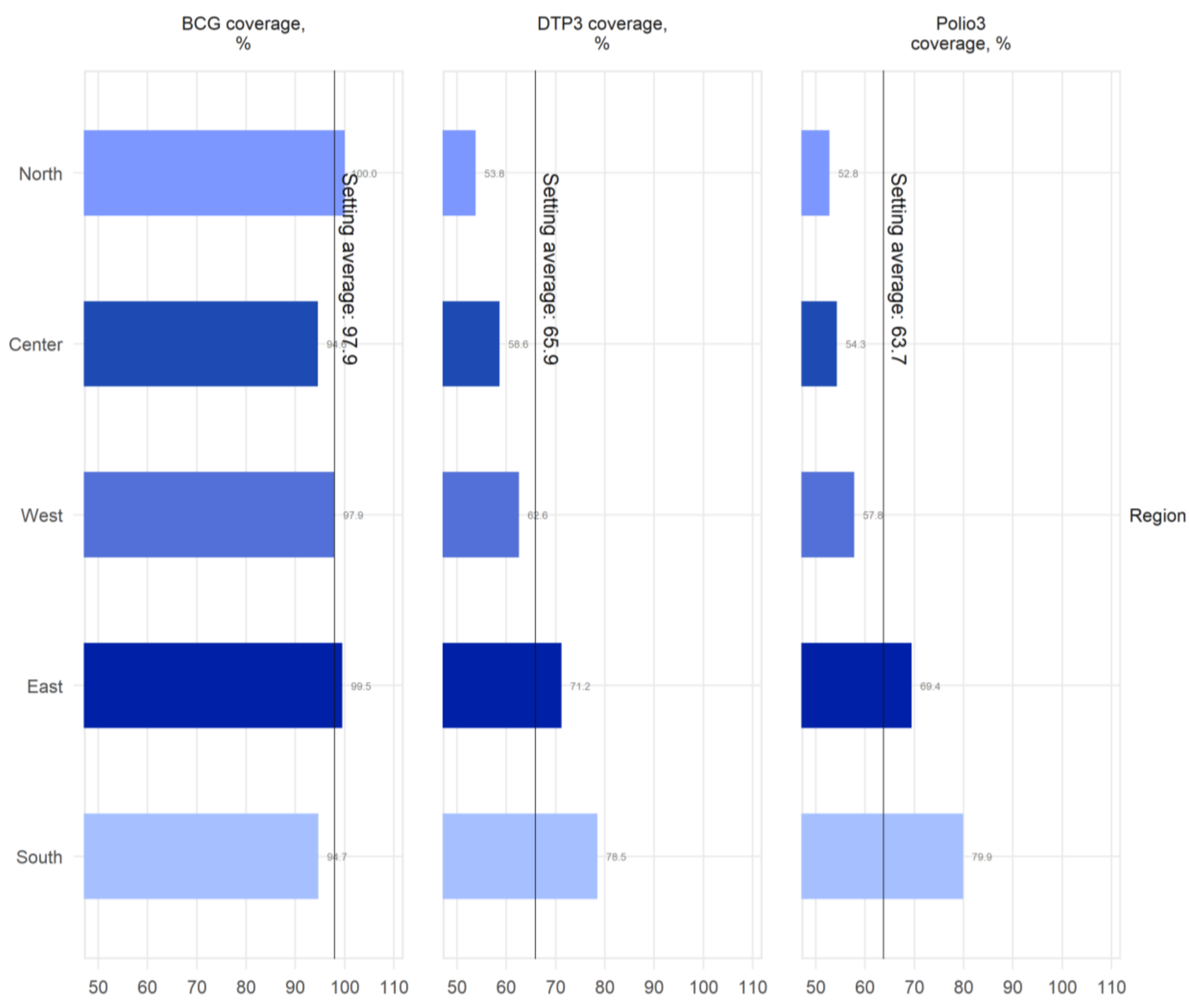


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Figure 17

Immunization Coverage with Hib3, HepB3 and Measles-Containing Vaccine by Region

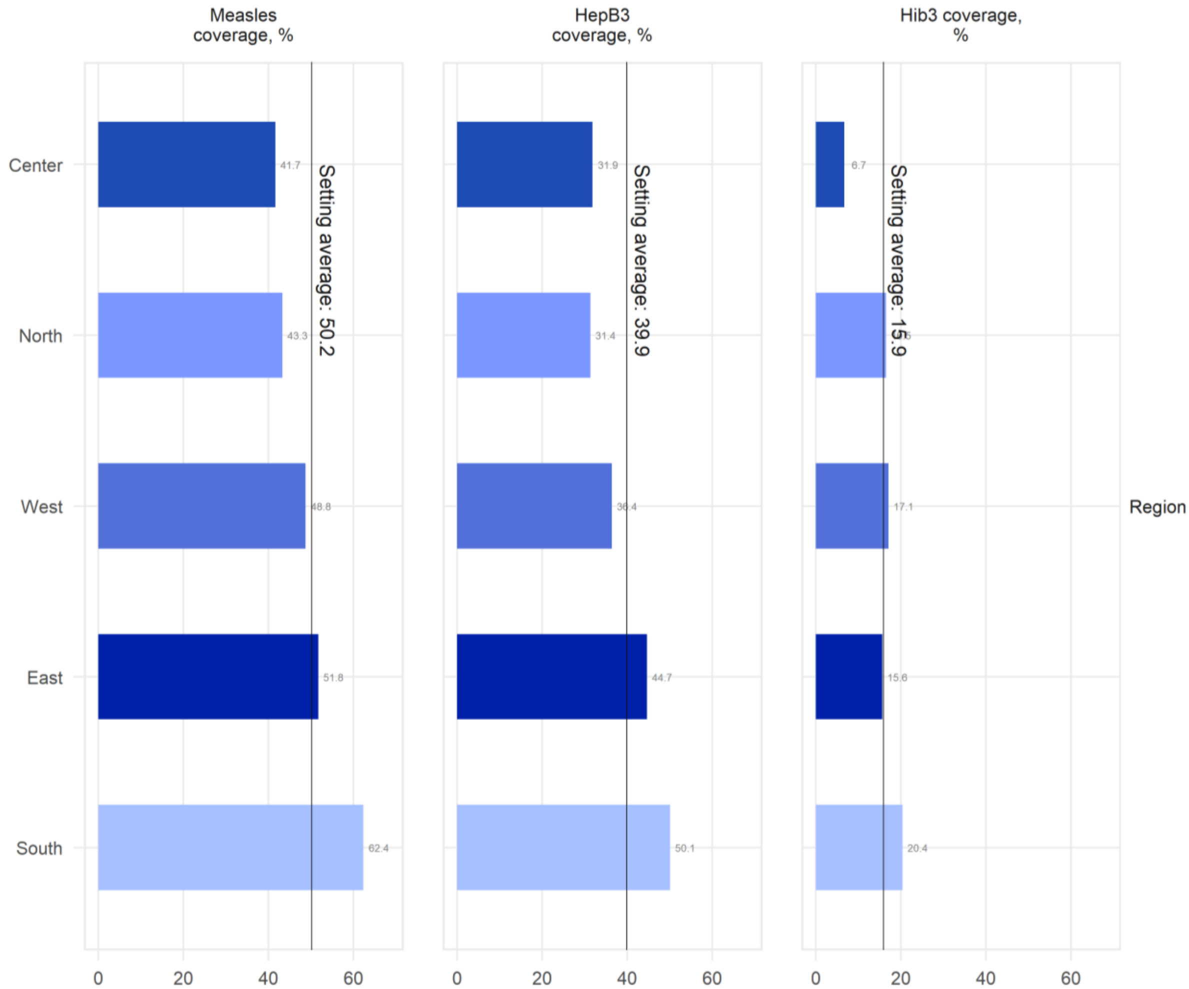

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Figure 18

Dropout Rates of the DTP and Polio Containing Vaccine by Region

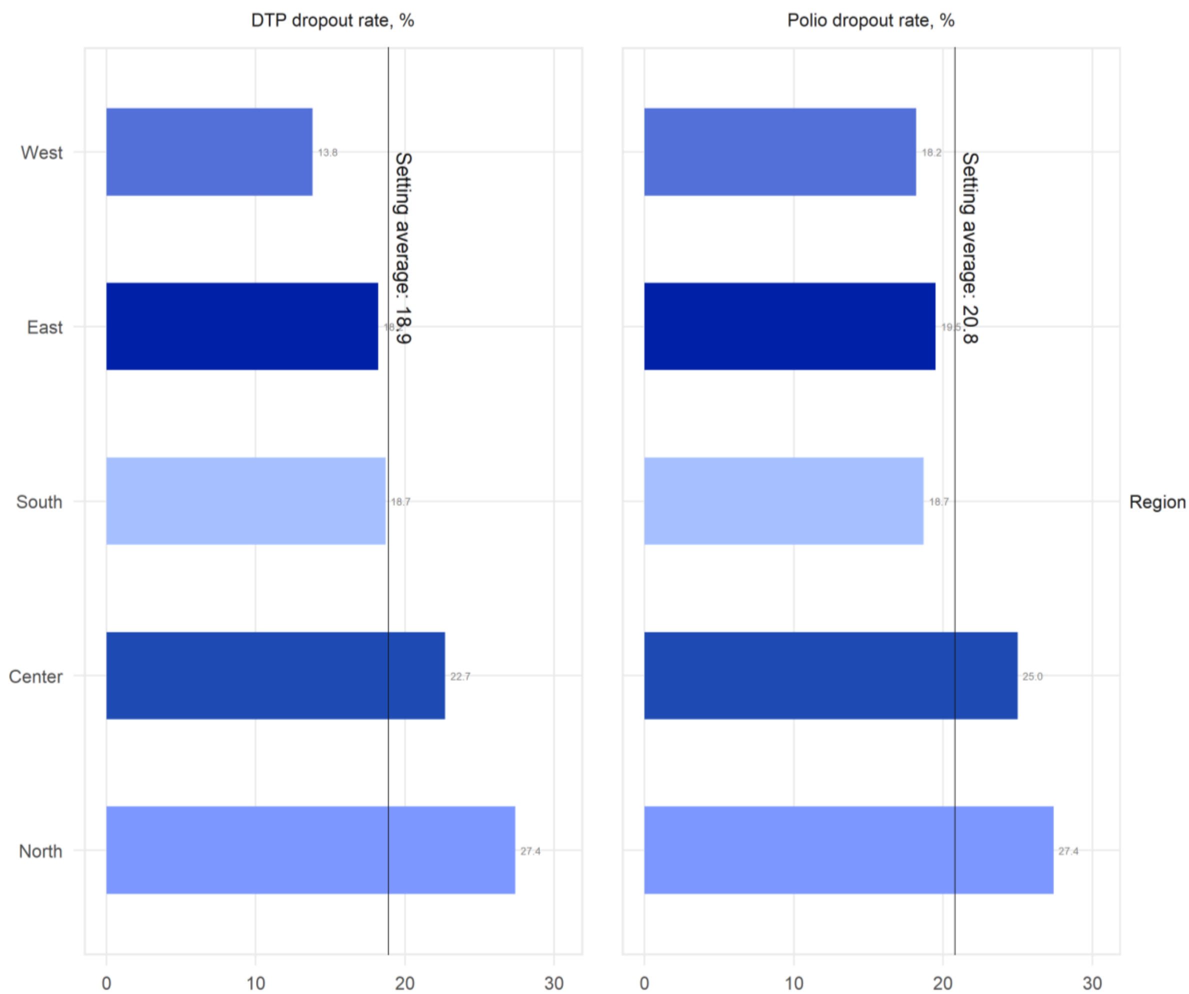

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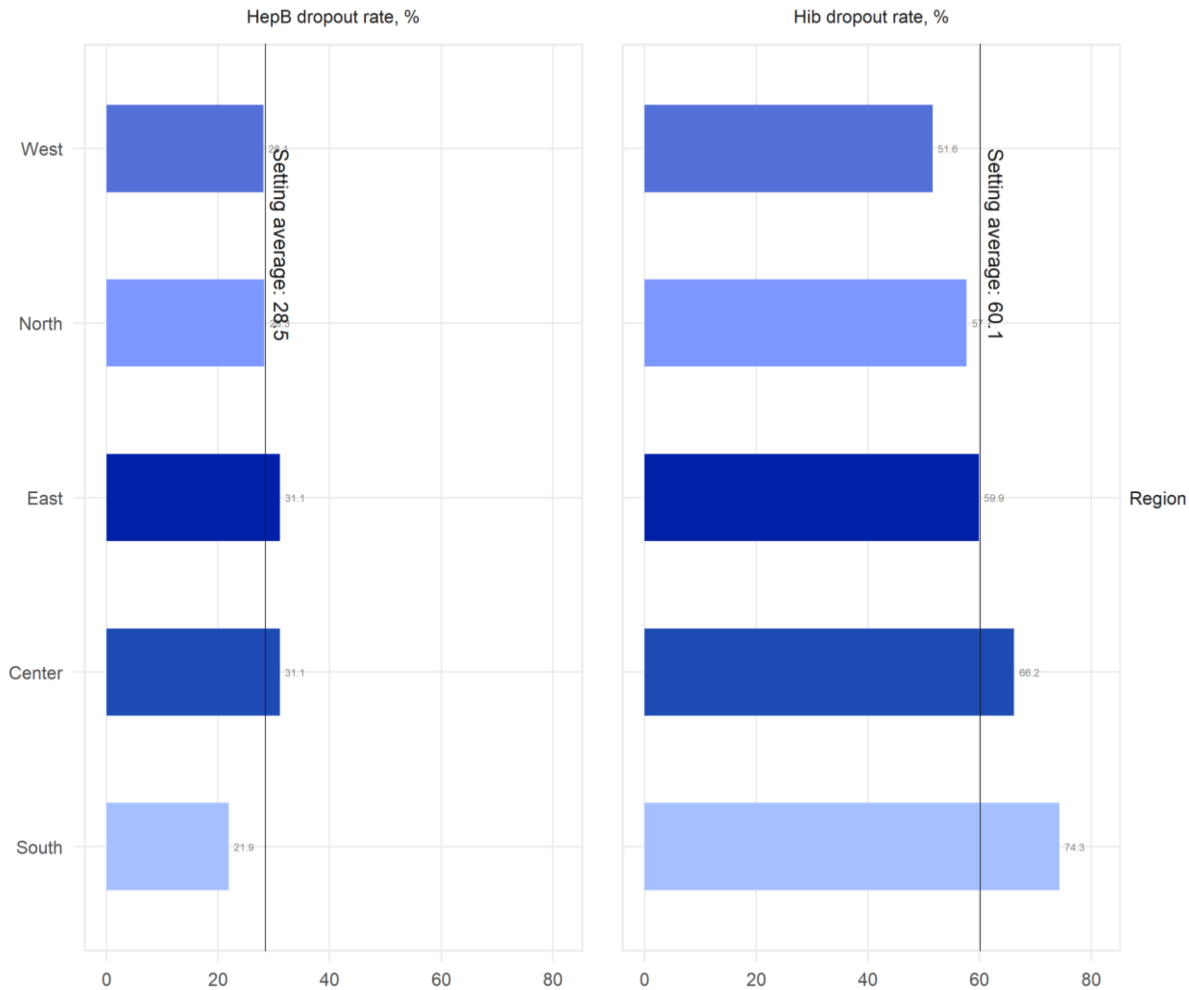
Figure 19

Dropout Rates of Hib and HepB Containing Vaccine by Region



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4.2. Simple Measures of Inequality

As a hinge to absolute and relative measures of inequality, this study will apply the difference and ratio of DTP3 vaccine coverage and DTP dropout rate estimates as it deemed to be one of the main proxies for the performance of the healthcare system. Table 9 presents calculated differences and ratios for dimensions of inequality, while Figure 20 portrays absolute gaps in coverage and dropout rates between selected subgroups. A bar graph employed for graphical representation highlights the major disparities between subgroups.

The clarity in showing disparities by equity dimensions makes simple measures an appealing instrument for forthright storytelling and yet sets a drawback due to the focus only on two subgroups. As described in the methodology, apart from the binary dimensions, the groups for pairwise comparison were chosen with the highest and lowest estimates for regions and type of settlement, and the richest and poorest wealth quantiles.

Table 9

Simple Measures of Inequality for the DTP3 Containing Vaccine and DTP Dropout Rate

Inequality dimension	Subgroups	Difference	Ratio
Diphtheria-tetanus-pertussis vaccine, the third dose			
Household economic status	Quantile 5 Quantile 1	-5.2	0.92
Mother's education	Higher education Secondary education	10.3	1.17
Area of residence	Urban Rural	-1.6	0.98
Type of settlement	Big city Small town	-1.7	0.97
Country region	South North	24.7	1.46
Child's sex	Female Male	-2.2	0.97
Diphtheria-tetanus-pertussis dropout rate			
Household economic status	Quantile 5 Quantile 1	0.6	1.04
Mother's education	Higher education Secondary education	-10.7	0.59
Area of residence	Urban Rural	-3.7	0.82
Type of settlement	Big city Small town	-5.2	0.76

(Continued on the next page)

Country region	North West	13.6	1.99
Child's sex	Female Male	7	1.45

The drastic differences were observed between the regions both for the vaccination coverage and the dropout rate. The Northern region, appearing at both sides of the spectrum with the lowest DTP3 coverage and highest DTP dropout rate estimates, falls 24.7% behind its Southern counterpart in coverage and reaches almost two times higher dropout rate than the Western region. More than 10% of the difference between higher and secondary education of mother is noticed both for the coverage and dropout rate. However, the sign of this relation explains the difference in the direction of the inequality. In other words, children with higher educated mothers had in 1.17 times higher vaccination coverage and 0.6 times lower dropout rate.

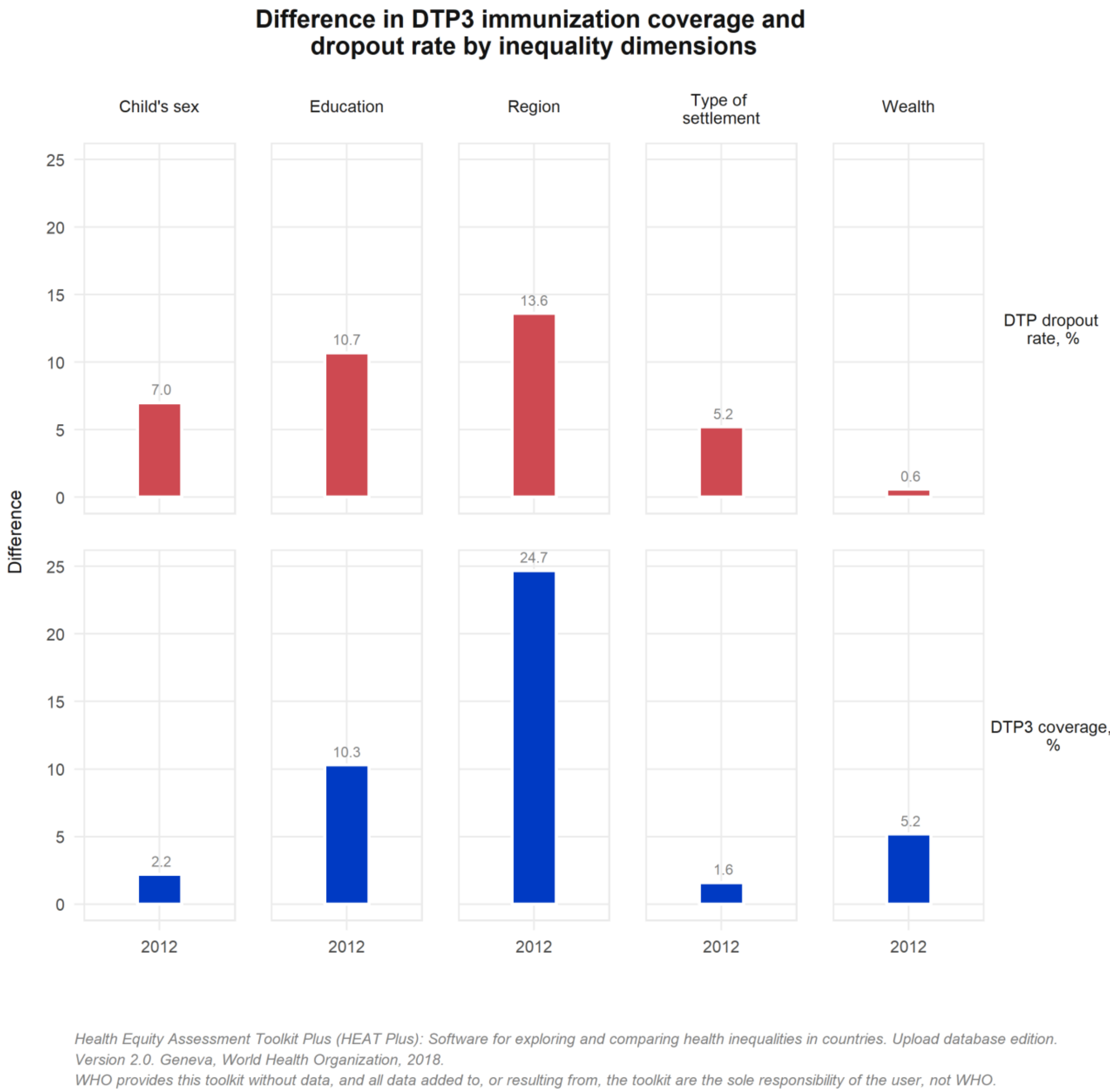
While the difference between the richest and the poorest quantiles was insignificant for the dropout rate, it attained to the level of 5.2% between the 1st and 5th quantiles for the DTP3 coverage with the latter one being inferior. The DTP3 coverage did not vary substantially between urban and rural areas, neither between settlement sizes. In contrast, the dropout rate was 0.76 times smaller for the big cities compared to the smaller ones. The difference by gender dimension revealed 2.2% lower coverage for girls and 1.45 higher dropout rates in comparison with boys.

The findings complement the literature on inequality in immunization and present the data estimated from MICS 2012 in Ukraine in a comparable way. The study conducted by Hoissenpoor, et al. (2016) on the data from DHS and MICS performed between 2010 and 2013 examines differences and ratios in DTP3 coverage among the children aged 12-23 months by wealth for 51 low- and middle-income countries omitting Ukraine. Although the published results varied by state, it is of particular interest to compare the simple measures of inequality with countries showing a historical similarity to Ukraine. Drawing a parallel between the former Soviet Union members, Ukraine exhibits the same trends in the pro-poor difference in DTP3 coverage between the 1st and 5th quantile as Kazakhstan (-2%) and Tajikistan (-1.3%). However, significantly higher differences or directions of inequality were observed in Kyrgyzstan (-19.3%) and Armenia (8.6%) respectively.

Despite its convenience in comparison and interpretation, simple measures of inequality can tell little about the distribution of health variable across the population share. This thread leads to the next section on complex measures to untangle inequality in DTP3 coverage.

Figure 20

Difference in DTP3 Containing Vaccine Coverage and DTP Dropout Rate by Inequality Dimensions



4.3. Complex Measures of Inequality

4.3.1. Concentration Index

This section focuses on quantifying the inequality by calculation of the Erreygers concentration index for the DTP3 containing vaccine, its interpretation, and graphical representation in the form of a concentration curve. Table 10 indicates the results obtained with the help of the command *conindex* applied in Stata v. 14, which allows the computation of both standard error and p-value for the calculated index. The obtained results are significant at 90% confidence level. For the purpose of accounting for the complexity of the sample design, *svy* prefix was applied together with the *conindex* command. Following concentration index calculation, the wealth-related inequality was portrayed by means of a concentration curve using the command *glcurve*.

Table 10

Erreygers Normalized Concentration Index Calculated for the DTP3 Containing Vaccine

	Index value	Standard error	P-value
Erreygers normalized concentration index	-0.09558514	0.05704684	0.0946

The findings show the existence of pro-poor inequality due to the negative sign of the index and the beneficial nature of the health variable. Thus, inequality follows the pattern of favoring inferior parts of the population, namely children from underprivileged families, according to the household economic status. The interpretation of the results suggests that for the equal allocation of vaccination coverage among the population subgroups, the redistribution of 9.55% of DTP3 vaccination from the poorest part of the population to the wealthiest half would be needed.

A pro-poor inequality in childhood immunization is rather an odd occasion as the similar studies on DTP3 coverage inequality (World Health Organization, 2018) or full immunization coverage (Hajizadeh, 2018; Restrepo-Méndez, et al., 2016) in low- and middle-income countries primarily show inequality favoring better-off. However, Hajizedah (2018) points out that a small number of countries from the pool of 46 states analyzed in his study exhibited inequality following pro-poor direction, including Kyrgyzstan (-0.227) and Armenia (-0.017) as graduates from Soviet bloc. The same was observed for Uzbekistan analyzed by Restrepo-Méndez, et al. (2016).

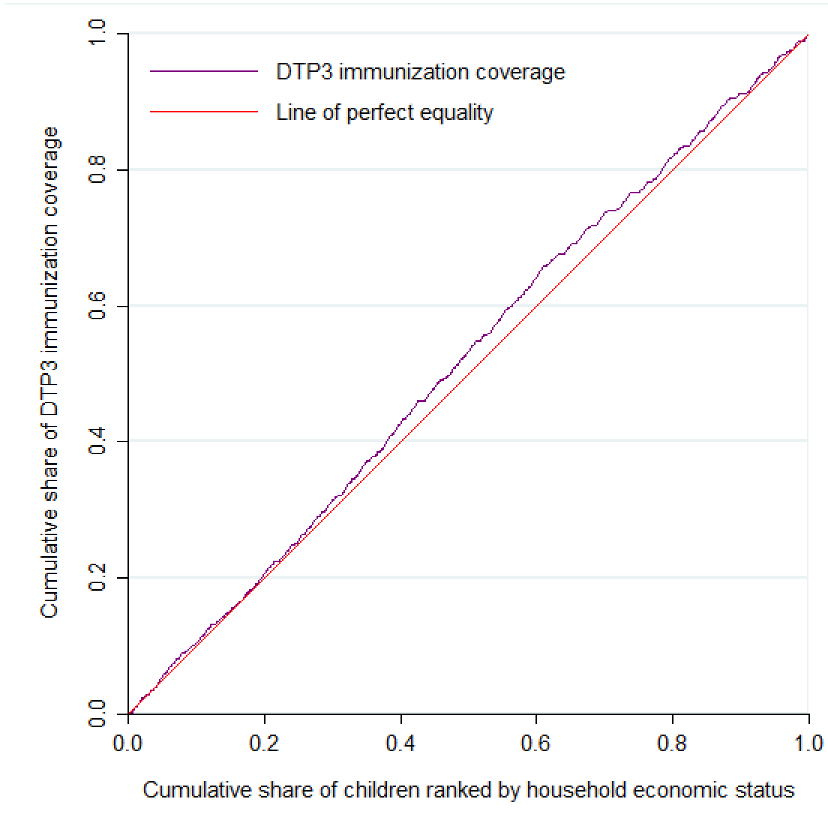
A possible explanation of such phenomenon could arise from the parental perception towards immunization per se, awareness of side effects and level of knowledge about disease and vaccination, which are observed in developed countries (Bardenheier, et al., 2004; Matsumura, Nakayama, Okamoto, & Ito, 2005). According to the study focused on the concerns related to vaccine hesitancy, the most commonly mentioned reasons in middle-income countries were lack of knowledge and understanding of vaccine significance as well as immunization benefits concerns, or so-called risk-benefit factors (Lane, MacDonald, Marti, & Dumolard, 2018). The survey on attitudes towards vaccination as a part of the Gallup World Poll 2018 permitted to have a closer look into vaccine awareness. Eastern Europe shows a considerably high level of affirmative answers on immunization knowledge (92%), however, the lowest numbers on the perception of the effectiveness of vaccines amongst the other regions (46% strongly agree and 19% somewhat agree) (Gallup, 2019).

After the widely disseminated by Ukrainian media case of death of 17-year-old adolescent the day after receiving the measles-containing vaccine in 2008, vaccine fear flourished immediately combined with the general suspicion in public healthcare (Lasco & Larson, 2020). A wave of such a vaccine hesitancy proves to be rooted and present until nowadays, as only 29% of respondents of the Wellcome Global Monitor 2018 survey in Ukraine considered vaccines safe (Gallup, 2019).

Figure 21 pictures inequality in DTP3 immunization by indicating a cumulative share of children ranked by the economic status and by vaccination coverage as x-values and y-values, respectively. An ideal scenario would be reached in a case when the concentration curve would coincide with the line of perfect equality drawn as a 45° line between two axes. A visual inspection of the concentration curve can suggest a gradient of pro-poor inequality expressed by its position above the line of perfect equality.

Figure 21

Concentration Curve for the DTP3 Containing Vaccine Coverage by Household Economic Status



4.3.2. Decomposition of Concentration Index

The estimated negative value of the Erreygers concentration index for DTP3 vaccination, indicating pro-poor inequality, was different from zero at the 90% confidence level. Therefore, the index was decomposed with the aim to define possible factors explaining the higher distribution of vaccination among the more inferior part of the population. Table 11 is constructed to present the results of the decomposition. The second column displays marginal effects obtained by applying the generalized linear model with the logistic identity link followed by elasticities for each explanatory variable, and Erreygers corrected partial concentration indices. Finally, the last two columns report the absolute and relative (percentage) contribution to socioeconomic inequality in DTP3 immunization.

The contribution of each of the regressors was obtained as the product of both marginal effect and partial concentration indices. In other words, the contribution of each dependent variable depends both on its impact on the receipt of DTP3 vaccination and inequality distribution of the variable by wealth. The sign of individual contributions follows a similar pattern as described for the Erreygers concentration index calculated for DTP3 coverage. Otherwise stated, if inequality were to be determined by one of the present independent variables, the positive (negative) sign of its contribution would indicate favoring better-off (worse-off). Negative contribution (or positive percentage contribution) could potentially be obtained either because a certain regressor (1) prevails among children from households of lower economic status and contributes to a higher probability of vaccination or (2) is prevalent among the children from the households of a higher economic status and is associated with lower probability of vaccination. Each contribution divided by the overall socioeconomic inequality measured by the Erreygers concentration index for DTP3 coverage gives the relative contribution of the determinants.

Overall, the results from the decomposition suggest that the lion's share of socioeconomic inequality falls on the economic part itself (91.63%), defined by the wealth index and subsequent wealth quantiles division. An analogous effect of wealth on pro-poor inequality in immunization was also observed in Kyrgyzstan (81.8%) (Hajizadeh, 2018). The possible factors of such parental behavior could be related to the loss of confidence because of a significant reduction in disease incidence after a sequence of stable vaccine coverages (Chen & Orenstein, 1996), or vaccine hesitancy related to adverse effects of vaccination (Bardenheier, et al., 2004). As the number of diphtheria cases during the years preceding the household survey in Ukraine was rather low (World Health Organization, 2019), the wealthier households might have changed their perception towards the immunization effectiveness considering the risks as prevailing over the benefits. On the other hand, inferior households confront higher burdens caused by vaccine-preventable diseases, which might affect parental decision-making.

On contrary to wealth-related inequality, mother's education contributes to a substantial reduction in inequality (-115.66%). Such contribution could be explained by the set of two positive components, namely marginal effect and concentration index. Statistically significant partial concentration index exhibits pro-rich tendency meaning that attainment of the highly educated mothers is concentrated among the wealthier households. A positive statistically significant impact

Table 11

Decomposition of Socioeconomic Inequalities in DTP3 Vaccination among the Children Aged Between 12 and 23 Months in Ukraine

Variable	**Partial Effect**	**Elasticity**	**Concentration Index**	**Contribution**	**% Contribution**
Quantile 1	0.0990782	0.07147768	-0.59131291 (***)	-0.04226567	44.217828
Quantile 2	0.1376637 (**)	0.11530912	-0.36007608 (***)	-0.04152006	43.437773
Quantile 3	0.0623239	0.04269576	-0.03371422	-0.00143945	1.5059396
Quantile 4	-0.008237	-0.0074669	0.31608048 (***)	-0.00236014	2.4691517
Quantile 5	*Base*	*Base*	*Base*	*Base*	*Base*
Household's wealth				-0.08758532	91.630692
Higher education (mother)	0.127389 (***)	0.32522023	0.33994338 (***)	0.11055647	-115.66282
Higher education (father)	-0.0892007 (**)	-0.21098081	0.40498062 (***)	-0.08544314	89.389562
Parental education				0.02511333	-26.273256
South	0.0518768	0.03031386	-0.04091171	-0.00124019	1.2974733
North	-0.1726707 (***)	-0.10425348	0.13595421 (***)	-0.0141737	14.82835
West	-0.0743026	-0.08343823	-0.21825039 (***)	0.01821043	-19.051524
Center	-0.1158646 (*)	-0.04973917	-0.04016632	0.00199784	-2.0901151
East	*Base*	*Base*	*Base*	*Base*	*Base*
Rural area	-0.0791694	-0.09111532	-0.68597323 (***)	0.06250267	-65.389528
Small town	-0.0043934	-0.00511264	0.02989578	-0.00015285	0.15990611
Big city	*Base*	*Base*	*Base*	*Base*	*Base*
External environment				0.0671442	-70.245438
Female	0.0242128	0.04581666	-0.10440461 (*)	-0.00478347	5.0044078
Birth order (1st)	0.1072758	0.23327516	0.17704683 (***)	0.04130063	-43.208209
Birth order (2-3rd)	0.1183622	0.19769858	-0.08603778	-0.01700955	17.795178
Birth order (≥4th)	*Base*	*Base*	*Base*	*Base*	*Base*
Female head of the household	0.0017713	0.00286373	-0.16146375 (***)	-0.00046239	0.48374481

(Continued on the next page)

Mother’s age (15-24)	0.1418426 (***)	0.16383317	-0.10403125 (*)	-0.01704377	17.830982
Mother’s age (25-29)	0.0656062	0.09355715	0.05244777	0.00490686	-5.1335009
Mother’s age (≥30)	*Base*	*Base*	*Base*	*Base*	*Base*
Predisposing demographic factors				0.00690832	-7.2273967
TV	-0.1083873	-0.02116884	-0.04758674 (**)	0.00100736	-1.0538838
Newspaper	0.5351365	0.0284798	-0.01453904	-0.00041407	0.43319394
Friends	0.0659626	0.06254734	0.05228071	0.00327002	-3.421054
Magazines	0.0761266	0.00470578	-0.0121064	-0.00005697	0.05960135
Radio	0.1716588	0.0070702	-0.01398357 (*)	-0.00009887	0.10343296
Health worker	0.1407142 (**)	0.49738378	-0.05361629	-0.02666787	27.899602
Internet	-0.0418834	-0.0196905	0.10140531 (***)	-0.00199672	2.088945
Books	0.0073746	0.00128578	0.03984756 (**)	0.00005124	-0.05360173
Other	-0.2011842	-0.00224472	-0.00197962	4.444e-06	-0.00464894
No trust	-0.0881536	-0.0088773	-0.00106816	9.482e-06	-0.00992031
Health beliefs				-0.02489196	26.04166

Note. *p<0.10, **p<0.05, ***p<0.01

of higher mother’s education on the child’s vaccination goes in lockstep with the literature on determinants of childhood immunization (Hajizadeh, 2018; Ndwandwe, et al., 2018; Zhu, et al., 2018).

Notwithstanding, father’s education portrays a different picture. Contrarily to studies examining the education of both parents (Djemaï, Renard, & Samson, 2019; Efendi, et al., 2019; Herliana & Douiri, 2017), which showed a positive effect of father’s education on vaccination uptake, the results suggested a negative impact of father’s schooling in Ukraine. The aforementioned effect could arise due to unobservable characteristics lying behind the father’s education, such as overall time devoted to child’s healthcare by father or susceptibility to vaccine hesitancy. As a general assumption, mothers often have a stronger impact on decisions concerning the child's health, including immunization (Luman, McCauley, Shefer, & Chu, 2003).

The disparities in wealth distribution are observed between both the country regions and types of settlement. The probabilities of vaccination varied among the regions, with the Northern part showing a significant negative effect on immunization uptake. In addition, the Northern region exhibits significant signs of pro-rich inequality. That fact could be explained by the location of the capital, Kyiv city, and nearest cities forming the country's biggest urban agglomeration, which is characterized by the larger labor productivity and higher educated population (OECD, 2018). The Northern region contributes to 14.82% of inequality in DTP3 immunization due to the combination of marginal effect and partial concentration index.

With regard to the type of settlement, the residence in rural areas of Ukraine is concentrated among the inferior part of the population according to the results of the partial concentration index (-0.69). Combined with the negative impact on the probability of a child's vaccination, the rural area of residence lessens the inequality in DTP3 immunization. Considering the multiple numbers of visits to the health facility for the receipt of the third dose of the vaccine of interest of the current study, the further investigation in access to healthcare, such as distance to the health center or costs of commuting, might help to explain the relationship between residence and vaccination uptake.

As reported in Table 11, the younger mothers have a significantly greater likelihood of having an immunized child comparing to mothers older than 30. However, the literature on the impact of mother's age on vaccination uptake does not follow one direction depending on the country-specific context (Efendi, et al., 2019; Mutua, Kimani-Murage, & Ettarh, 2011; Zhu, et al., 2018). Together with the higher distribution of younger mothers in households with reduced circumstances (partial concentration index is -0.1) younger age of mothers contributes to 17.83% of immunization inequality.

This research considers predisposing demographic characteristics, such as the child's gender and birth order, the gender of the household head, and mother's age, as in itself determined by the accidence of birth. Therefore, the concentration index of DTP3 immunization was demographically adjusted to control for the confounding effect of the inescapable features. Table 12 shows the values of the Erreygers concentration index for DTP3 vaccination before and after accounting for demographics. The demographically adjusted index shows the inequality that could have existed if predisposing need factors were equally distributed in society. Overall, the adjusted index is reinforced, indicating a higher pro-poor inequality owing to predisposing demographic characteristics, which favor the better-off.

Apart from adjusted for demographics index, Table 12 shows the residual part calculated as subtraction of contributions of all the factors from the Errreygers concentration index for DTP3 vaccination.

Table 12

Erreygers Concentraion Index Calcualated for the DTP3 Containing Vaccine, its Demographics Adjusted Version and Residual

	Index value
Erreygers concentration index	-0.09558514
Erreygers concentration index (demographics adjusted)	-0.10249346
Erreygers concentration index (residual)	-0.0822737

Among the sources of information for mothers regarding the health of the family, the trust in recommendations of healthcare workers is the only determinant that shows a significant positive impact on the probability of DTP3 vaccination. As a result of prevalence among the inferior part of the population, the trust in health workers' advice adds on 27.89% to inequality.

The distribution of the rest sources of trust among the population reveals the other side of the immunization story. Thus, trust in the web sources is concentrated among the richer parts, which is also explained by the presence of Internet connection among the better-off. Consideration of books by mothers in family healthcare decision-making follows a pro-rich pattern as well, although in a lesser extent than the web source trust. Highly educated mothers may appeal to healthcare textbooks. Hajizadeh (2018) points out that well-educated mothers also maintain larger social networks, from which they might gather health-related information. The confidence in friends' and relatives' suggestions, or so-called social capital, on healthcare issues is concentrated among the wealthier population and goes in line with Hajizadeh's study yielding to a higher probability of immunization; however, it is not statistically significant.

Chapter 5. Policy Implication and Conclusion

5. Policy Implication and Conclusion

This Chapter presents policy implications derived from the results of the research (Section 5.1) and summarizes the thesis with conclusion (Section 5.2).

5.1. Policy Recommendations

This thesis provides evidence of socioeconomic gradient in DTP3 vaccination coverage among the children aged between 12 and 23 months in Ukraine. First of all, this research explores immunization coverage of the common vaccines from the schedule of routine immunization of Ukraine by the background characteristics. Secondly, it quantifies inequality in DTP3 vaccination in the form of the concentration index (CI=-0.096), which demonstrates a pro-poor direction. Based on the result of the concentration index, the thesis provides decomposition into specific determinants that might have affected inequality, facilitating deeper analysis and opening the door for tailored policy implications.

Apart from the economic status of the household, factors such as the country's region, age, and health beliefs of the mother contribute to an explanation of the inequality in DTP3 vaccination. Additionally, parental education plays a significant role in the child's immunization. From the policy perspective, these results lead to the three major recommendations.

Firstly, the inequality favoring the inferior parts of the population implies that wealthier households tend to be reluctant to vaccinate their children. The reasons behind such parental decision could appear due to the loss of confidence in vaccination as a result of a plunge in disease incidence achieved because of the previously high vaccination rates (Chen & Orenstein, 1996), or a niggle of doubt in vaccine safety and efficacy (Bardenheier, et al., 2004; Matsumura, Nakayama, Okamoto, & Ito, 2005). In both cases, proper communication conveying the message of vaccination importance from the side of the pediatricians, and through the media channels should be conducted. Among the communication channels, the focus should primarily fall on TV and Internet sources as the ones showing the negative impact on immunization uptake.

Secondly, the policy design to improve vaccination coverage as a part of the target of 80% coverage in every district and 90% at the national level according to Global Vaccine Action Plan (World Health Organization, 2013) should account for the regional variations in socioeconomic inequalities. Specific attention should be directed towards the Northern region, including Kyiv agglomeration, which shows the lowest immunization coverages and strong pro-rich inequality.

Finally, for equity-oriented analysis in immunization, it is crucial to rely on the high-quality and timely available data. The data in this thesis was derived from the MICS performed in 2012 in Ukraine as the most recent publicly available source of information that allows making a comprehensive examination of the state of childhood immunization. However, the results should be understood as a reflection of the survey year. Hence, developing a strong national health information system with reporting immunization data that could be disaggregated by the multiple inequality dimensions on an ongoing basis will enable sound health inequality monitoring and evaluation.

5.2. Conclusion

The last century has witnessed a great deal of improvement on the path of coping with vaccine-preventable diseases globally. Despite gaining success proven by the formidable results in childhood mortality reduction tracing its roots to vaccine introduction during the Soviet Union rule, Ukraine ironically shows a decline in immunization coverage during the Decade of Vaccines 2011-2020. The disparities between the population subgroups revealed by the descriptive statistics suggest that the provision of vaccines free of costs is still way off from universal healthcare coverage goal. Unlike most of the studies examining low- and middle-income countries, the findings in this research imply an inequality favoring the more inferior parts of the population.

During the period of its independence, Ukraine had a bitter experience of outbreaks of diphtheria in the 1990s, poliomyelitis cases in 2015, and measles in 2018-2019. Still healing from the most recent one, the country significantly improved its coverage with the measles-containing vaccine. However, an immunization “memory” is short. The old scars from faraway diphtheria incidence lull into a false sense of security towards dangerous vaccine-preventable disease, as the coverages with the DTP3 containing vaccine remain insufficient in Ukraine. Thus, the policy actions and interventions capturing diverse dimensions of inequality in immunization and tailoring the most susceptible population groups should be undertaken until it will be too late to learn another tough lesson of history.

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Appendices

Appendix 1: Immunization Coverage Disaggregated by Background Characteristics, Children Aged 12-23 Months

Variable	Mean coverage	Linearized standard error	95% Confidence interval	
Bacillus Calmette-Guérin vaccine				
Total	0.9790862	0.0069817	0.9653604	0.9928119
By wealth				
Quantile 1	0.979067	0.0111063	0.9572323	1.000902
Quantile 2	0.9836385	0.008917	0.9661079	1.001169
Quantile 3	0.9620993	0.0322464	0.8987038	1.025495
Quantile 4	0.9752185	0.0133892	0.9488958	1.001541
Quantile 5	0.9919694	0.0052284	0.9816906	1.002248
By education				
Secondary	0.9832597	0.0072808	0.9689458	0.9975735
Higher	0.9767239	0.0100519	0.9569621	0.9964858
By region				
South	0.9469678	0.0376654	0.8729186	1.021017
North	1	-	-	-
West	0.979607	0.0108366	0.9583024	1.000912
Center	0.9462571	0.0186762	0.9095401	0.982974
East	0.9946547	0.0054069	0.9840249	1.005285
By area of residence				
Rural	0.9714759	0.0113368	0.9491881	0.9937636
Urban	0.9896377	0.0053296	0.9791599	1.000115
By type of settlement				
Big city	0.9896377	0.0053296	0.9791599	1.000115
Small town	0.9649963	0.0203137	0.9250601	1.004933
Rural	0.9782424	0.0093112	0.9599368	0.9965481
By child's sex				
Male	0.9743945	0.0120227	0.9507581	0.9980309

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Female	0.9842808	0.0063333	0.9718298	0.9967319
Diphtheria-tetanus-pertussis vaccine, first dose				
Total	0.8490628	0.0205534	0.8086553	0.8894702
By wealth				
Quantile 1	0.8383062	0.0327578	0.7739054	0.9027071
Quantile 2	0.9173655	0.0211063	0.8758711	0.9588598
Quantile 3	0.8788874	0.0386075	0.8029863	0.9547886
Quantile 4	0.8272773	0.0545098	0.7201126	0.934442
Quantile 5	0.7917172	0.0496361	0.6941339	0.8893005
By education				
Secondary	0.852372	0.0389185	0.7758593	0.9288848
Higher	0.847186	0.0222261	0.8034901	0.8908818
By region				
South	0.9720276	0.0131337	0.9462072	0.997848
North	0.8123913	0.0484007	0.717237	0.9075457
West	0.7648963	0.0481789	0.6701779	0.8596148
Center	0.812721	0.0423107	0.7295394	0.8959027
East	0.8925793	0.0373352	0.8191793	0.9659794
By area of residence				
Rural	0.8715907	0.0224725	0.8274104	0.915771
Urban	0.8178965	0.0373878	0.7443931	0.8914
By type of settlement				
Big city	0.8178965	0.0373878	0.7443931	0.8914
Small town	0.8873026	0.0358575	0.8168077	0.9577975
Rural	0.8551508	0.0263688	0.8033105	0.9069911
By child's sex				
Male	0.8265019	0.030023	0.7674775	0.8855262
Female	0.8740187	0.0264624	0.8219945	0.926043
Diphtheria-tetanus-pertussis vaccine, third dose				
Total	0.6596882	0.0275766	0.6054733	0.713903
By wealth				

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Quantile 1	0.6702443	0.0496329	0.5726673	0.7678212
Quantile 2	0.7221143	0.0414975	0.6405313	0.8036974
Quantile 3	0.726054	0.0672059	0.5939291	0.8581789
Quantile 4	0.5851333	0.0684482	0.450566	0.7197006
Quantile 5	0.6175458	0.0539461	0.5114893	0.7236023
By education				
Secondary	0.5943768	0.0467011	0.5025638	0.6861897
Higher	0.6967853	0.0328892	0.6321261	0.7614445
By region				
South	0.7847491	0.0488901	0.6886326	0.8808657
North	0.5382348	0.0602335	0.4198175	0.6566522
West	0.625748	0.058319	0.5110943	0.7404016
Center	0.5859941	0.0589341	0.4701311	0.701857
East	0.7116644	0.0556682	0.6022222	0.8211065
By area of residence				
Rural	0.6664011	0.0323465	0.6028088	0.7299934
Urban	0.6504168	0.0480379	0.5559755	0.7448581
By type of settlement				
Big city	0.6504168	0.0480379	0.5559755	0.7448581
Small town	0.6668403	0.0513004	0.5659851	0.7676955
Rural	0.66594	0.0386796	0.589897	0.741983
By child's sex				
Male	0.6700367	0.036288	0.5986954	0.741378
Female	0.6482175	0.0377424	0.5740169	0.7224181
Measles containing vaccine				
Total	0.5024853	0.0287193	0.4460235	0.558947
By wealth				
Quantile 1	0.4298862	0.0632263	0.305584	0.5541884
Quantile 2	0.5037978	0.0558983	0.3939024	0.6136932

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Quantile 3	0.6043702	0.0577029	0.4909271	0.7178134
Quantile 4	0.4945706	0.0659709	0.3648725	0.6242686
Quantile 5	0.4876834	0.055412	0.378744	0.5966228
By education				
Secondary	0.4584309	0.0493363	0.3614363	0.5554254
Higher	0.5271373	0.0335541	0.4611704	0.5931042
By region				
South	0.6235088	0.0503957	0.5244315	0.7225862
North	0.4334849	0.0549218	0.3255093	0.5414605
West	0.4884316	0.0571694	0.3760373	0.6008259
Center	0.4168517	0.0497112	0.3191201	0.5145833
East	0.5175232	0.0630209	0.3936249	0.6414214
By area of residence				
Rural	0.4960126	0.0387033	0.4199224	0.5721028
Urban	0.5113608	0.0426586	0.4274944	0.5952271
By type of settlement				
Big city	0.5113608	0.0426586	0.4274944	0.5952271
Small town	0.5780794	0.0644029	0.451464	0.7046948
Rural	0.4107484	0.0426319	0.3269347	0.4945622
By child's sex				
Male	0.5299763	0.038287	0.4547046	0.605248
Female	0.472316	0.0396012	0.3944606	0.5501714
Poliomyelitis containing vaccine, the first dose				
Total	0.8426266	0.0206751	0.80198	0.8832733
By wealth				
Quantile 1	0.8296734	0.0321752	0.7664177	0.892929
Quantile 2	0.9176812	0.0208465	0.8766975	0.958665
Quantile 3	0.8553132	0.0404518	0.7757861	0.9348404
Quantile 4	0.823261	0.055111	0.7149143	0.9316077

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Quantile 5	0.7917172	0.0496361	0.6941339	0.8893005
By education				
Secondary	0.8361072	0.0392444	0.7589537	0.9132607
Higher	0.8463325	0.0223237	0.8024447	0.8902203
By region				
South	0.9853045	0.0089359	0.9677367	1.002872
North	0.8017546	0.0482393	0.7069175	0.8965917
West	0.7602229	0.0484138	0.6650427	0.8554031
Center	0.7935341	0.0459928	0.7031135	0.8839546
East	0.8816039	0.0375193	0.8078419	0.9553658
By area of residence				
Rural	0.8634314	0.0226398	0.8189223	0.9079406
Urban	0.8138601	0.0376452	0.7398506	0.8878696
By type of settlement				
Big city	0.8138601	0.0376452	0.7398506	0.8878696
Small town	0.8794507	0.0365	0.8076927	0.9512087
Rural	0.8466121	0.0259124	0.7956689	0.8975552
By child’s sex				
Male	0.8189564	0.0299836	0.7600095	0.8779034
Female	0.8688399	0.0267804	0.8161904	0.9214894
Poliomyelitis containing vaccine, the third dose				
Total	0.6369821	0.0278235	0.5822818	0.6916823
By wealth				
Quantile 1	0.5848957	0.0540107	0.4787121	0.6910792
Quantile 2	0.727595	0.0412125	0.6465723	0.8086178
Quantile 3	0.6790872	0.0692938	0.5428575	0.815317
Quantile 4	0.5692134	0.0693901	0.4327943	0.7056324
Quantile 5	0.6300163	0.0524944	0.5268137	0.7332189
By education				

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Secondary	0.5431263	0.0444021	0.4558329	0.6304196
Higher	0.6903324	0.033152	0.6251565	0.7555082
By region				
South	0.7986491	0.047918	0.7044436	0.8928547
North	0.527576	0.0604279	0.4087763	0.6463757
West	0.5779045	0.0581662	0.4635514	0.6922576
Center	0.5434495	0.0605912	0.4243289	0.6625701
East	0.694314	0.054637	0.5868992	0.8017289
By area of residence				
Rural	0.6342048	0.0329436	0.5694387	0.698971
Urban	0.6408221	0.0481683	0.5461246	0.7355196
By type of settlement				
Big city	0.6408221	0.0481683	0.5461246	0.7355196
Small town	0.6271502	0.0505442	0.5277817	0.7265188
Rural	0.6416118	0.0415365	0.5599522	0.7232715
By child's sex				
Male	0.6372235	0.0357427	0.5669542	0.7074927
Female	0.6367148	0.0382956	0.5614266	0.7120029
Hepatitis B vaccine, the first dose				
Total	0.6183322	0.0306732	0.5580296	0.6786348
By wealth				
Quantile 1	0.6442536	0.0674262	0.5116955	0.7768118
Quantile 2	0.6726524	0.0495112	0.5753148	0.76999
Quantile 3	0.5710503	0.0617533	0.449645	0.6924557
Quantile 4	0.5826112	0.068122	0.4486852	0.7165373
Quantile 5	0.6195758	0.0620864	0.4975156	0.7416359
By education				
Secondary	0.5705023	0.0511117	0.4700181	0.6709865
Higher	0.6454214	0.0344854	0.577624	0.7132188
By region				
South	0.6066204	0.0834684	0.4425239	0.770717

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North	**0.5632597**	**0.0712805**	**0.4231242**	**0.7033953**
West	0.6083156	0.064171	0.4821571	0.734474
Center	0.5593926	0.0542537	0.4527313	0.6660539
East	0.6776958	0.0561638	0.5672793	0.7881122
By area of residence				
Rural	0.6625775	0.0371057	0.5896286	0.7355264
Urban	0.557173	0.0507898	0.4573217	0.6570243
By type of settlement				
Big city	0.557173	0.0507898	0.4573217	0.6570243
Small town	0.6538056	0.0562902	0.5431406	0.7644705
Rural	0.6717718	0.0476968	0.5780013	0.7655424
By child's sex				
Male	0.6405901	0.0373518	0.5671575	0.7140226
Female	0.5937345	0.0418693	0.5114206	0.6760484
Hepatitis B vaccine, the third dose				
Total	0.3989236	0.0282616	0.3433621	0.4544851
By wealth				
Quantile 1	0.4350151	0.067275	0.3027543	0.5672758
Quantile 2	0.4405252	0.0521726	0.3379552	0.5430951
Quantile 3	0.4439006	0.0639346	0.318207	0.5695942
Quantile 4	0.3217967	0.060831	0.2022047	0.4413888
Quantile 5	0.375357	0.0609573	0.2555167	0.4951974
By education				
Secondary	0.3631828	0.0437616	0.2771488	0.4492168
Higher	0.4191659	0.0355002	0.3493736	0.4889582
By region				
South	0.5006662	0.0539006	0.3946991	0.6066334
North	0.3142275	0.0665539	0.1833844	0.4450705
West	0.3644775	0.0559728	0.2544366	0.4745184

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Center	0.3185662	0.0479209	0.2243551	0.4127773
East	0.4471495	0.0601556	0.3288852	0.5654138
By area of residence				
Rural	0.4357546	0.0359733	0.365032	0.5064771
Urban	0.348013	0.0433992	0.2626913	0.4333347
By type of settlement				
Big city	0.348013	0.0433992	0.2626913	0.4333347
Small town	0.4409318	0.0550014	0.3328005	0.5490631
Rural	0.430328	0.0459737	0.339945	0.5207111
By child's sex				
Male	0.3554149	0.0362332	0.2841815	0.4266483
Female	0.4470063	0.0378504	0.3725934	0.5214191
Haemophilus influenzae type b containing vaccine, the first dose				
Total	0.7592791	0.0262079	0.7077543	0.810804
By wealth				
Quantile 1	0.7596542	0.0409533	0.6791399	0.8401685
Quantile 2	0.8010129	0.0516497	0.6994695	0.9025563
Quantile 3	0.7265084	0.0643094	0.6000759	0.8529409
Quantile 4	0.7542189	0.0568517	0.6424482	0.8659896
Quantile 5	0.7499647	0.0516403	0.6484398	0.8514897
By education				
Secondary	0.7956944	0.0409383	0.7152095	0.8761793
Higher	0.7387824	0.0312836	0.6772788	0.8002861
By region				
South	0.9476042	0.0195173	0.9092331	0.9859753
North	0.7419562	0.0580275	0.627874	0.8560384
West	0.6876024	0.0524393	0.5845064	0.7906983
Center	0.7289556	0.0498224	0.6310047	0.8269066
East	0.7503414	0.0573686	0.6375545	0.8631283
By area of residence				
Rural	0.7692336	0.0317154	0.7068811	0.831586

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Urban	0.745647	0.0442467	0.6586579	0.8326362
By type of settlement				
Big city	0.745647	0.0442467	0.6586579	0.8326362
Small town	0.7631462	0.0521705	0.6605789	0.8657135
Rural	0.7755835	0.0351769	0.7064256	0.8447414
By child's sex				
Male	0.7425601	0.0343574	0.6750134	0.8101069
Female	0.7776937	0.0358945	0.7071249	0.8482624
Haemophilus influenzae type b containing vaccine, the third dose				
Total	0.1594743	0.0234567	0.1133584	0.2055902
By wealth				
Quantile 1	0.061146	0.0299921	0.0021814	0.1201106
Quantile 2	0.1781546	0.0459096	0.0878962	0.2684129
Quantile 3	0.1948166	0.0495708	0.0973603	0.2922729
Quantile 4	0.191196	0.0613387	0.070604	0.3117881
Quantile 5	0.1603922	0.0456351	0.0706735	0.250111
By education				
Secondary	0.0636128	0.0183539	0.027529	0.0996966
Higher	0.213431	0.033843	0.1468956	0.2799664
By region				
South	0.204219	0.0637341	0.0789175	0.3295205
North	0.1646873	0.0544634	0.0576122	0.2717625
West	0.1714238	0.0463374	0.0803244	0.2625232
Center	0.066566	0.0210341	0.0252129	0.1079191
East	0.155715	0.0456047	0.066056	0.245374
By area of residence				
Rural	0.1580774	0.0310094	0.0971129	0.2190419
Urban	0.1613874	0.0358616	0.0908832	0.2318915
By type of settlement				
Big city	0.1613874	0.0358616	0.0908832	0.2318915
Small town	0.210748	0.0528727	0.1068001	0.3146959

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Rural	0.1031347	0.0280812	0.0479269	0.1583425
By child's sex				
Male	0.1699197	0.0304959	0.1099647	0.2298746
Female	0.1479697	0.032325	0.0844186	0.2115208
Full immunization				
Total	0.0578841	0.0115085	0.0352585	0.0805097
By wealth				
Quantile 1	0.0209959	0.0103779	0.0005931	0.0413986
Quantile 2	0.1037041	0.0367997	0.0313563	0.176052
Quantile 3	0.0477336	0.0270165	-0.0053806	0.1008478
Quantile 4	0.053407	0.0162375	0.0214843	0.0853298
Quantile 5	0.0560637	0.0236517	0.0095647	0.1025628
By education				
Secondary	0.0367939	0.0149419	0.0074183	0.0661695
Higher	0.0697127	0.0154321	0.0393735	0.100052
By region				
South	0.0404155	0.0146053	0.0117017	0.0691293
North	0.0578776	0.0289586	0.0009453	0.1148099
West	0.0789483	0.0307107	0.0185714	0.1393252
Center	0.0467551	0.0191043	0.0091963	0.084314
East	0.0517447	0.0179784	0.0163995	0.08709
By area of residence				
Rural	0.0567135	0.0154308	0.0263767	0.0870503
Urban	0.0594884	0.0172468	0.0255815	0.0933953
By type of settlement				
Big city	0.0594884	0.0172468	0.0255815	0.0933953
Small town	0.0780983	0.0285436	0.021982	0.1342146
Rural	0.0344184	0.0110126	0.0127676	0.0560691
By child's sex				
Male	0.0415265	0.0116398	0.0186427	0.0644103
Female	0.0758559	0.018921	0.0386574	0.1130544

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Zero-dose immunization				
Total	0.0057273	0.0023422	0.0011226	0.010332
By wealth				
Quantile 1	0.0050913	0.0041464	-0.0030606	0.0132431
Quantile 2	0.0026096	0.0026245	-0.0025502	0.0077693
Quantile 3	0.0053215	0.0053509	-0.0051984	0.0158415
Quantile 4	0.00925	0.007639	-0.0057683	0.0242682
Quantile 5	0.0059283	0.0047571	-0.0034242	0.0152807
By education				
Secondary	0.0024797	0.0020119	-0.0014757	0.0064352
Higher	0.007551	0.0034774	0.0007144	0.0143876
By region				
South	0	-	-	-
North	0	-	-	-
West	0.0059911	0.0060565	-0.005916	0.0178981
Center	0.0401008	0.0159239	0.0087943	0.0714073
East	0	-	-	-
By area of residence				
Rural	0.005319	0.0032516	-0.0010738	0.0117117
Urban	0.0062861	0.0033114	-0.000224	0.0127963
By type of settlement				
Big city	0.0062861	0.0033114	-0.000224	0.0127963
Small town	0.0055369	0.0055951	-0.005463	0.0165368
Rural	0.0050912	0.0031699	-0.0011409	0.0113232
By child’s sex				
Male	0.0063872	0.0039277	-0.0013347	0.014109
Female	0.0050011	0.0024792	0.000127	0.0098753

Appendix 2: Vaccination Dropout Rates by the Background Characteristics, Children Aged 12-23 Months

Variable	Mean coverage	Linearized standard error	95% Confidence interval	
Diphtheria-tetanus-pertussis containing vaccine dropout rate				
Total	0.1896402	0.0213192	0.1477272	0.2315532
By wealth				
Quantile 1	0.168062	0.0391489	0.0910962	0.2450277
Quantile 2	0.1968468	0.0374943	0.123134	0.2705597
Quantile 3	0.1528335	0.057245	0.0402913	0.2653757
Quantile 4	0.2421439	0.0532961	0.1373652	0.3469227
Quantile 5	0.1741714	0.0430492	0.0895379	0.2588049
By education				
Secondary	0.2579953	0.0417308	0.1759536	0.340037
Higher	0.1508142	0.0231732	0.1052564	0.196372
By region				
South	0.1872784	0.0474662	0.0939612	0.2805957
North	0.2741565	0.0636811	0.1489612	0.3993518
West	0.138304	0.0277461	0.083756	0.192852
Center	0.226727	0.049487	0.1294368	0.3240171
East	0.1822015	0.0466611	0.0904671	0.2739359
By area of residence				
Rural	0.2049733	0.0273226	0.1512579	0.2586888
Urban	0.1684632	0.0338685	0.1018787	0.2350477
By type of settlement				
Big city	0.1684632	0.0338685	0.1018787	0.2350477
Small town	0.2204623	0.0428013	0.1363161	0.3046085
Rural	0.1887106	0.0330032	0.1238272	0.2535941
By child's sex				
Male	0.1564652	0.0204752	0.1162115	0.1967189
Female	0.2264126	0.0353795	0.1568574	0.2959678
Poliomyelitis vaccine dropout rate				

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Total	**0.2081637**	**0.0222971**	**0.1643282**	**0.2519993**
By wealth				
Quantile 1	0.2447777	0.0496108	0.1472442	0.3423112
Quantile 2	0.1920696	0.0345273	0.12419	0.2599492
Quantile 3	0.1885833	0.0622095	0.0662811	0.3108856
Quantile 4	0.2540476	0.0544947	0.1469125	0.3611828
Quantile 5	0.1617009	0.0411289	0.0808425	0.2425593
By education				
Secondary	0.2987917	0.0434211	0.2134269	0.3841564
Higher	0.1566483	0.0228294	0.1117664	0.2015301
By region				
South	0.1866553	0.0466964	0.0948516	0.2784591
North	0.2741786	0.0587477	0.1586822	0.3896749
West	0.1823184	0.0422633	0.0992299	0.2654069
Center	0.2500846	0.0507087	0.1503928	0.3497764
East	0.1951328	0.0457238	0.1052411	0.2850245
By area of residence				
Rural	0.2292266	0.0291394	0.1719393	0.2865139
Urban	0.1790403	0.0341569	0.1118888	0.2461919
By type of settlement				
Big city	0.1790403	0.0341569	0.1118888	0.2461919
Small town	0.2523004	0.0452287	0.1633819	0.3412189
Rural	0.2050002	0.0350831	0.1360279	0.2739726
By child's sex				
Male	0.181733	0.0223616	0.1377707	0.2256953
Female	0.2374341	0.036058	0.166545	0.3083232
Hepatitis B vaccine dropout rate				
Total	0.2848983	0.0255589	0.2346501	0.3351465
By wealth				
Quantile 1	0.2525187	0.0418015	0.1703381	0.3346994
Quantile 2	0.3422892	0.0491625	0.2456372	0.4389413

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Quantile 3	0.1991543	0.0447747	0.1111284	0.2871802
Quantile 4	0.2846527	0.0603562	0.1659941	0.4033114
Quantile 5	0.3229896	0.0617239	0.2016421	0.4443371
By education				
Secondary	0.2779756	0.0384469	0.20239	0.3535613
Higher	0.2888191	0.0338168	0.2223362	0.3553019
By region				
South	0.2189904	0.044697	0.1311174	0.3068635
North	0.2833931	0.0550079	0.1752491	0.3915372
West	0.2811261	0.054372	0.1742322	0.38802
Center	0.3108961	0.0574977	0.1978572	0.423935
East	0.3109497	0.0511762	0.2103386	0.4115608
By area of residence				
Rural	0.2755959	0.0290787	0.2184279	0.3327639
Urban	0.2977568	0.045406	0.2084898	0.3870239
By type of settlement				
Big city	0.2977568	0.045406	0.2084898	0.3870239
Small town	0.250708	0.0419461	0.168243	0.3331729
Rural	0.3016822	0.0397649	0.2235056	0.3798589
By child's sex				
Male	0.3436949	0.0377645	0.2694509	0.4179388
Female	0.2199207	0.0255318	0.1697259	0.2701155
Haemophilus influenzae type b containing vaccine dropout rate				
Total	0.6014426	0.0306411	0.5412021	0.661683
By wealth				
Quantile 1	0.6985082	0.047595	0.6049362	0.7920802
Quantile 2	0.6228583	0.0577071	0.5094061	0.7363106
Quantile 3	0.5412485	0.058996	0.4252622	0.6572348
Quantile 4	0.5630228	0.0682217	0.4288988	0.6971469
Quantile 5	0.5895725	0.0679858	0.4559123	0.7232328
By education				

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Secondary	0.7320816	0.0434442	0.6466702	0.817493
Higher	0.5279109	0.0373357	0.4545087	0.6013131
By region				
South	0.7433852	0.064305	0.6169613	0.8698091
North	0.5772689	0.078828	0.4222928	0.732245
West	0.5161785	0.058007	0.4021365	0.6302206
Center	0.6623896	0.0533754	0.5574533	0.7673259
East	0.5996969	0.0640521	0.4737703	0.7256235
By area of residence				
Rural	0.6111562	0.038417	0.5356283	0.6866841
Urban	0.5881402	0.0499547	0.4899291	0.6863513
By type of settlement				
Big city	0.5881402	0.0499547	0.4899291	0.6863513
Small town	0.5523982	0.0619696	0.4305659	0.6742305
Rural	0.6724488	0.0421784	0.589526	0.7553716
By child's sex				
Male	0.5726404	0.0395174	0.4949492	0.6503317
Female	0.6331655	0.0406075	0.5533309	0.7130001

Appendix 3: Immunization Coverage with DTP3 Containing Vaccine in Slice of the Other Determinants Used in Decomposition

Variable	Mean coverage	Linearized standard error	95% Confidence interval	
Diphtheria-tetanus-pertussis containing vaccine, the third dose				
Total	0.6596882	0.0275766	0.6054733	0.713903
By father's education				
Secondary	0.6727095	0.0438582	0.5864525	0.7589666
Higher	0.6421157	0.0415971	0.5603055	0.7239259
By child's birth order				
1st born	0.6774246	0.0351839	0.6082497	0.7465995
2nd or 3rd child	0.6381121	0.0428788	0.5538083	0.7224159
4th child >	0.5051085	0.1109747	0.2869216	0.7232954
By mother's age				
15-24	0.7257269	0.0448392	0.6375701	0.8138836
25-29	0.6467034	0.0395283	0.5689882	0.7244186
30>	0.6077351	0.0456797	0.5179259	0.6975443
By gender of the household head				
Male	0.6587292	0.0337814	0.5923159	0.7251425
Female	0.6611834	0.0414968	0.5796019	0.7427649
By mother's health beliefs				
TV	0.6382654	0.0846504	0.4718437	0.8046871
Newspaper	0.9570085	0.0434243	0.8716368	1.04238
Friends	0.6965228	0.0552728	0.5878572	0.8051884
Magazines	0.6763131	0.1369298	0.4071107	0.9455154
Radio	0.8679331	0.1229248	0.6262645	1.109602
Healthcare worker	0.6753265	0.0292437	0.6178337	0.7328194
Internet	0.6121734	0.0962477	0.4229515	0.8013953
Pharmacy	0.5811419	0.0872625	0.4095849	0.7526989
Other	0.3150356	0.2676514	-0.2111638	0.841235
No trust	0.4086297	0.1622434	0.0896611	0.7275983