# Determinants of Childhood Immunisation in sub-Saharan Africa: a Multilevel Analysis


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**ABSTRACT**

This study investigates the relationship between childhood vaccination and household wealth as well as various other socio-economic indicators in sub-Saharan Africa. Compared to other regions worldwide, sub-Saharan Africa is lagging behind in terms of its vaccination rate, leading to a vast number of premature deaths each year. Whereas previous studies used varying wealth indices derived from the DHS and UNICEF MICS surveys, this study uses the International Wealth Index as measure of household wealth, allowing data to be compared over time and place. Multilevel linear regression models are used to examine the relationship in a dataset consisting of 422 regions within 37 countries from 2000 through 2018. The analyses indicate that there is a positive relationship between household wealth and the vaccination rate. Additionally, various other socio-economic determinants are found to be of importance, among which maternal education, health expenditure, and household size. The results indicate that most of the variance in the vaccination rate can be explained by characteristics at the national level. The main conclusion is that childhood vaccination is positively influenced by household wealth.

***Keywords*: ** Childhood Immunisation, sub-Saharan Africa, Multilevel Analysis, International Wealth Index

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# 1. Introduction

Childhood immunisation is an important element contributing to the achievement of the 2030 Agenda for Sustainable Development consisting of the 17 Sustainable Development Goals (Arsenault et al., 2017a). This agenda prioritises the rights and needs of the world's most vulnerable people in order to ensure that no one is left behind. Immunisation has been described as a so-called 'super buy' for the achievement of the Sustainable Development Goals as the benefits from immunisation go beyond its immediate impact as a cost-effective public health intervention (Kelleher, 2019). It has been shown that immunisation can contribute to reaching 14 of the 17 Sustainable Development Goals among which the goals of no poverty, zero hunger, good health and wellbeing, gender equality, industry, innovation and infrastructure, and partnership for the goals (World Health Organization, 2019). However, many inhabitants of low- and middle-income countries continue to be neglected in terms of lifesaving health interventions, especially in the case of childhood immunisation.

Currently, immunisation helps to save 2 to 3 million lives per year from diphtheria, tetanus, whooping cough, and measles (Requejo et al., 2020). Dedicated global vaccination campaigns have so far led to the eradication of smallpox, while the eradication of polio and measles is likely to happen in the coming decade (Aaby & Benn, 2020). Despite the importance of childhood immunisation, there remains a wide gap in the global share of under-vaccinated children between various regions in the world. Especially Central, Eastern, Southern, and Western Africa stand out in terms of the share of under-vaccinated children, not only due to the relatively high share across these regions but also due to the fact that this share has increased instead of decreased in West and Central Africa during the past decade (Requejo et al., 2020). Furthermore, there tend to be large differences in the immunisation rate among these African countries, ranging from 42% in Somalia to 98% in Rwanda based on the third dose of diphtheria, tetanus, and pertussis (DTP3) coverage in the year 2019 (United Nations Children Fund Data, 2020). As the herd immunity threshold for sustained control of vaccine-preventable diseases like DTP, polio, and measles lies at 80% or higher, many African countries still have a long way to go in order to reach this target (Plans-Rubió, 2012). Hence, a better understanding of barriers towards immunisation is needed.

Extensive research has been done on the determinants of vaccination (Arsenault et al., 2017a; Hutchins et al., 1993; Sridhar et al., 2014; Szilagyi & Rodewald, 1996). Low immunisation rates are partially attributed to missed opportunities for vaccination. The World Health Organization defines missed opportunities for vaccination as ''any contact with health services by an individual (child or person of any age) who is eligible for vaccination (e.g. unvaccinated or partially vaccinated and free of contraindications to vaccination), which does not result in the person receiving one or more of the vaccine doses for which he or she is eligible'' (World Health Organization, 2020, What is a missed opportunity for vaccination? section, para 1). Sridhar et al. (2014) did an extensive literature survey on barriers towards immunisation in low- and middle-income countries, finding 352 different reasons in 57 studies. Among these reasons ''health care practices, false contraindications, logistic issues related to vaccines, and organisational limitations'' (p. 6870) were the most prominent. Besides missed opportunities for vaccination, there are also many other reasons for low vaccination coverage as not every individual gets into contact with health services. A study conducted on 45 low- and middle-income countries supported by the Global Alliance for Vaccines and Immunizations showed that there are five main indicators impacting vaccination coverage namely asset ownership, maternal education, place of residence, gender, and child malnutrition (Arsenault et al., 2017a, 2017b). Uthman et al. (2018) argued that lack of media access, being considered the poorest households, and living in poorer neighbourhoods are important determinants of missed opportunities for vaccination in sub-Saharan Africa. Simultaneously, Adebowale et al. (2019) showed that there are large disparities in the vaccination rate between poor and rich households in Nigeria. Using an asset index, they found that 39% of the children in rich households get fully vaccinated compared to 5% in poor households. When household wealth is divided into five successive categories, children belonging to the wealthiest households are 13 times more likely to get vaccinated compared to those belonging to the poorest households (Demographic and Health Surveys Program [DHS], n.d.).

It is thus argued that indicators reflecting household wealth, so-called asset-based wealth indices, are important determinants of the level of vaccination coverage and the amount of missed opportunities for vaccination. Asset-based wealth indices are based on the possession of consumer durables and housing characteristics measured through household surveys like the DHS and UNICEF MICS surveys (Smits & Steendijk, 2015). They are ''calculated using easy-to-collect data on a household's ownership of selected assets, such as televisions and bicycles; materials used for housing construction; and types of water access and sanitation facilities.'' (DHS, n.d., Wealth Index Construction section, para 1). The International Wealth Index by the Global Data Lab is the first comparable sub-national asset-based wealth index with data covering the entire developing world across time (Smits & Steendijk, 2015). This is in contrast to other wealth indices which are not comparable across place and time as household surveys tend to change their questions, depending on a countries' characteristics and the year in which the survey is conducted. Therefore, each survey leads to different compositions of the asset-based wealth indices. The International Wealth Index is constructed using the same criteria for the components in each country and year, therefore ensuring that data can be compared over time and place.

Gaining further insight into the socio-economic determinants of vaccination rates and missed opportunities for vaccination becomes increasingly more important as the aforementioned statistics on Africa show. The COVID-19 crisis once more emphasises the need for efficient vaccination campaigns as reaching the herd immunity threshold seems like the only way out of this crisis (Randolph & Barreiro, 2020). As earlier studies are primarily based on the DHS and UNICEF MICS surveys, the goal of this paper is to contribute to the existing literature by using the International Wealth Index in order to gain new insights into the relationship between household wealth and the vaccination rate. Simultaneously, the effect of other socio-economic variables on the vaccination rate will be examined. This study will therefore answer the following research questions:

- *What is the relationship between the International Wealth Index and the vaccination rate of children aged 1?*
- *How and to what extent is this relationship influenced by other socio-economic characteristics at the regional as well as national level?*

This study aims to complement the current knowledge on vaccination coverage by answering the aforementioned research questions. Most successes in increasing the vaccination rate can be achieved in sub-Saharan Africa due to the disproportionately low vaccination rate compared to other regions worldwide. Therefore, the focus of this study will be on sub-Saharan Africa. The research questions will be empirically examined using multilevel regression analyses on 422 regions in 37 sub-Saharan African countries over the period 2000-2018.

The remainder of this paper is structured as follows. Chapter 2 will discuss the current knowledge of the relationship between household wealth and the vaccination rate as well as other determinants of vaccination like geographical location, maternal education, household size, and power dynamics. Chapter 3 consists of the methodology, while Chapter 4 presents the corresponding results. This paper will finish with a discussion of the results and a conclusion in Chapter 5 and Chapter 6 respectively.

# 2. Theoretical Framework

Vaccines have been able to prevent more health-related problems, like death, disabilities, and related suffering, than any other medical intervention or discovery (Uthman et al., 2018).

Besides solving health inequities and corresponding long-term effects on one's physical, cognitive, and emotional development, vaccines have a much broader impact on societies worldwide as they are able to improve the life expectancy of recipients, thus fostering health- as well as wealth-equities (Bloom et al., 2005). One of the reasons for this is that healthy lives are becoming increasingly more important in the broader definition of one's wealth (Andre et al., 2008). But wealth is also influenced by health through other channels, healthier children are better able to focus in school and are able to learn more efficiently, stimulating future opportunities (Bloom et al., 2005). Furthermore, healthy individuals are more productive, leading to less sick leaves, which leads to more income and thus more wealth. A third channel is through increased savings and investments. Healthier people are expected to live longer and therefore have a greater incentive to save for their retirement. Simultaneously, their savings and investments can be used to develop a country and its economy further, leading to a demographic dividend as economic development often goes hand in hand with lower mortality and fertility rates. Besides, immunisation programmes have led to the development of widespread primary care infrastructures throughout the developing world, leading to lower child mortality while simultaneously empowering women's positions within their families, further prompting health, social, and economic benefits. Studies have shown that the annual return on investment in vaccinations is between 12% and 18% (Bloom et al., 2005). Vaccines are thus able to stimulate economic growth globally due to lower mortality and morbidity rates, saving billions of US dollars annually.

Nonetheless, the number of missed opportunities for vaccinations has remained fairly stable between 1993 and 2015, leading to an updated missed opportunities for vaccination strategy in order to reach the global vaccination coverage targets (Uthman et al., 2018). Increasing the global vaccination coverage of DTP alone would decrease the number of premature deaths by 1.5 million per year. Furthermore, childhood vaccinations do not only prevent death from diseases like DTP, measles, and tuberculosis (BCG) but they also enable other healthcare services during the process of vaccination which further reduces the number of premature deaths (Adebowale et al., 2019). Besides the benefits in terms of health, vaccines are able to prevent 24 million recipients and their relatives from falling into poverty until 2030, thus improving the wellbeing of a vast amount of people (World Health Organization, 2019). Hence, understanding the determinants of vaccination is crucial for increasing the vaccination rate in order to reduce the number of premature deaths at the regional, as well as national, and global level.

This chapter will first examine and analyse how the vaccination rate has developed over the past couple of decades before diving further into the determinants of the vaccination rate. The main focus will be on the current literature examining the relationship between household wealth and the vaccination rate. Additionally, other prominent factors influencing the uptake of vaccinations are examined, respectively geographical location, maternal education, household size, and power dynamics.

## 2.1. Developments in Vaccination

Since the introduction of the smallpox vaccine in 1796, the prevalence of diseases has reduced significantly all over the world primarily due to breakthroughs in medicine leading to vaccines that are effective against 28 human diseases (Vanderslott et al., 2013). Global vaccination coverage among one-year-olds has surpassed the level of 80% for various of these vaccines despite many countries in the world still experiencing far lower vaccination rates. Vaccination rates also differ significantly within countries and between various vaccines. The vaccination rate for DTP3 is often taken as the benchmark for a countries vaccination program as three contact moments with healthcare providers at specific points in time are needed to complete all doses of the DTP vaccine (Arsenault, 2017a; GAVI, n.d.; Vanderende et al., 2018). When examining this rate, it is often found that vaccination coverage is lower in poorer countries with rich countries often having vaccination coverage rates well above 90% (Vanderslott et al., 2013). Although there are various poor countries like Bangladesh, Burundi, and Rwanda that score high in terms of their vaccination rate, sub-Saharan African countries stand out in terms of their low vaccination rate, with the Central African Republic, Chad, and Guinea even scoring lower than 50% in terms of measured DTP3 coverage in 2017.

Since 1990, the number of child deaths caused by vaccine-preventable diseases has decreased from 5.5 million deaths per year to 1.8 million deaths in 2017 (Vanderslott et al., 2013). Nonetheless, the increase in global vaccination coverage has slowed down over the past few years, primarily due to stalled development in sub-Saharan Africa. The main issue is not that sub-Saharan African children are not vaccinated at all, as an estimated 85% of children-aged-1 receive a first dose of the measles vaccine, but a lack of uptake of so-called booster doses, as only 64% of the children receive a second dose. Other vaccines show the same development, with the percentage decreasing further for each additional dose needed. For example, for the DTP vaccine to be fully effective, three doses are needed. The Global Alliance for Vaccines and Immunizations found that only 7% of the children in the 73 poorest countries receive all necessary vaccinations while 80% of the children receive one or more vaccines

(Berkley, 2017). The main issue besides a lack of vaccination is thus so-called under-vaccination.

The statistics on vaccination coverage as well as on vaccine-preventable diseases and corresponding mortality rates are even more shocking when a closer look is taken at sub-Saharan Africa. While approximately 25% of the children born each year are from sub-Saharan Africa, 40-50% of child morbidity and deaths from vaccine-preventable diseases take place there (Madhi & Rees, 2018). In 2017, only 17 from the 47 sub-Saharan African countries reached a first dose measles coverage above 90%. At the same time, Zimbabwe was the only sub-Saharan African country to reach the threshold of 80% in terms of DTP3 coverage which is set in the World Health Organization's Global Vaccine Action Plan (Bangura et al., 2020).

At this moment, vaccines are able to save 2 to 3 million lives annually. However, the World Health Organization estimates that a further 1.5 million deaths could be prevented from vaccine-preventable diseases (Vanderslott et al., 2013). However, various studies argue that this is a very low estimate as it is believed that the smallpox vaccine alone has saved 5 million lives per year since the eradication of smallpox in 1977. Vaccines are able to create immunity ''by introducing a weakened or killed form of the pathogen that makes us ill – such as bacteria or viruses – or its toxins or one of its surface proteins'' (Vanderslott et al., 2013, How vaccines work & herd immunity section, para. 1). The higher the vaccination rate, the higher the protection rate within a population, leading to reduced or even stopped transmission of viruses. Hence, improving our understanding of the determinants of vaccination coverage, especially in sub-Saharan African countries, can help improve the vaccination rate thus reducing the prevalence of diseases and premature deaths among children.

## 2.2. Household Wealth

Many studies have examined the socio-economic determinants of childhood immunisation across a wide variety of countries in order to efficiently set up vaccination programmes. Various studies argued that large inequalities in childhood immunisation can be ascribed to differences in household wealth (Adebowale et al., 2019; Mutua et al., 2021; Uthman et al., 2018; Zeitlyn et al., 1992). Household wealth is often measured through asset-based wealth indices based on standardised questionnaires examining household characteristics, like the DHS and UNICEF MICS surveys. The level of household wealth is derived from an index based on the possession of consumer durables such as telephones, refrigerators, and bicycles, the availability of utility services like water and electricity, and housing characteristics, like the quality of floor material and the toilet facility (Bondy et al., 2009; Smits & Steendijk, 2015).

Through this, a household's socio-economic position is measured enabling comparison between richer and poorer quintiles within a country (Arsenault et al., 2017b). These indices are thus able to explain the aforementioned differences in immunisation rates. The next paragraphs will dive further into various theoretical explanations for these differences.

Various developing countries offer vaccinations free of charge while other developing countries ask for a fee. However, in both types of countries household wealth has proven to be a strong determinant for childhood immunisation (Bondy et al., 2009). One explanation for this is that even though the vaccines might be free of charge, a lack of money, in general, tends to lead to poor health-seeking behaviour (Jamil et al., 1999). Many parents from low socio-economic households experience time constraints and financial costs when taking part in the process of vaccination, limiting them from accessing care for their children. As a result, children belonging to poorer households build up less immunity compared to children belonging to higher socio-economic households. Children belonging to lower socio-economic households often become not fully immunised against vaccine-preventable diseases while they simultaneously build up less natural immunity due to a deprivation of nutritious foods (Adedokun et al., 2017). Besides, poorer parents often make a different cost-benefit analysis when deciding to vaccinate their children or not (Favin et al., 2012). For these parents, the costs of vaccinating their children are much higher as they often have to travel long distances while they also have to wait for hours at vaccination centra, preventing them from working and thus feeding their family. At the same time, many mothers have conflicting priorities as they often have to balance taking care of their families with having to work at one or more jobs. More often than not, the latter goes before the former as studies in Bangladesh, Guinea, and Kenya showed (Gaturuku, 1990; Millimouno et al., 2006; Uddin et al., 2008). Healthcare providers might not be aware of these limitations but are able to tackle them by choosing more convenient locations as well as timeslots for healthcare services (Jheeta & Newell, 2008). This would also tackle the issue that there is a large gap between the ability of rich and poor households to access public health facilities (Adebowale et al., 2019). Not all public health facilities are able to provide vaccinations and a lack of transportation can thus be an important factor in determining whether a child gets vaccinated or not. Since richer households are more likely to have their own mode of transport and are more likely to be able to pay for public transport, the chance of children belonging to these households being vaccinated is higher.

A second factor that lowers the vaccination rate among poorer households is the so-called user fees (Arsenault et al., 2017a; Ridde & Morestin, 2011). Even though many low- and middle-income countries offer vaccines free of charge, some of these countries charge a fee in order to get a vaccination. However, many poor households do not have the funds to pay for the vaccines upfront. As the benefits of vaccines often take place in the long-term, many parents opt to not vaccinate their children, thus creating a higher risk for their children in terms of catching a disease in the future (Arsenault et al., 2017b). At the same time, the risk of experiencing a financial shock when a child does get severely ill increases for the parents which could potentially put further strains on their future financial situation. Hence, household wealth is an important determinant for underlying structural wellbeing.

A third factor associated with lower vaccination rates among poorer households is parental accessibility to media. Uthman et al. (2018) found that mothers who had media access are 4% less likely to have a child that can be classified with missed opportunities for vaccination. Media access was determined as access to radio, television, and/or newspapers. Many sub-Saharan African countries experience scarcity in local healthcare providers while many households do not have access to media (Jung et al., 2015). Because of this, it is more difficult to obtain information on healthcare. Hence, so-called communication inequalities arise due to differences in access to healthcare information. Jung et al. (2015) further showed that the effects of radio and television are important in reducing the healthcare discrepancies between children from high- and low-socioeconomic households. Mass media is able to increase immunisation coverage through reminder and recall systems targeted at parents (Wiysonge et al., 2012). Simultaneously, they are able to increase parental knowledge on the effects of vaccination on their own health, as well as on their families' and communities' health. The effect of mass media is even larger for children of mothers with no or lower educational attainment as it is able to increase the understanding of vaccination programmes which increases the level of trust in vaccinations (Bugvi et al., 2014). In Pakistan, the National Immunisation Campaign has been able to increase the level of awareness about the benefits of timely and complete vaccination, which led to higher immunisation coverage. The same has been shown by mass media campaigns in sub-Saharan Africa aimed at increasing awareness of HIV and AIDS (Jung et al., 2015). These campaigns revolved around the ways through which HIV can be transmitted and which preventive measures can be undertaken. Findings showed that awareness increased among the groups that had access to media providing healthcare information. Hence, household assets, like radio, television and/or newspapers, are important factors for increasing the vaccination coverage of children as they are able to provide parents with valuable information.

## 2.3. Other Determinants

Besides household wealth, there are many other determinants of the vaccination rate. Uthman et al. (2018) found that ''child's age, birth order, number of under-five children, maternal age, wealth index, education attainment, media access and neighbourhood socio-economic disadvantages'' (p. 2400) were important determinants of missed opportunities for vaccination. Arsenault et al. (2017b) found that maternal education, poverty, child malnutrition, and urban/rural residence are also important determinants of the vaccination rate. Based on these and other studies in this field, the following variables will be examined further: geographical location, maternal education, household size, and power dynamics.

### 2.3.1. Geographical Location

The geographical location of a household is an important determinant of vaccination (Jamil et al., 1999; Shrivastwa et al., 2015). Mitchell et al. (2009) showed that inequities in vaccination coverage can be found in rural as well as urban areas. However, the level of inequity is higher in rural areas and is higher for poorer households, who are more likely to live in rural areas. A study in Senegal found that 71% of the children living within 10 kilometres of a health centre were fully vaccinated compared to 10% of the children in remote villages (Favin et al., 2012). Hence, children in urban areas tend to have better vaccination coverage compared to children in rural areas but within both areas, children of richer households tend to be better off than children of poorer households.

Households in urban areas are closer to healthcare providers, thus making it easier to get children vaccinated (Adedokun et al., 2017). On the one hand, because distances between communities and healthcare providers are smaller which reduces the amount of time needed for the process of vaccination. On the other hand, the smaller distances eliminate the need for more expensive modes of transportation, thus enabling more children from lower as well as higher wealth quintiles to get vaccinated. Healthcare providers in rural areas are often located at a larger distance, making it more difficult for parents to gain information on vaccination campaigns and of corresponding benefits to their children's health (Adedokun et al., 2017). Besides, Onsomu et al. (2015) argued that many residents of rural areas in developing countries still uphold traditional health practices which limit the usage of modern medical science, like vaccines, as their study on Kenya showed. Hence, the uptake of vaccinations in rural areas is limited by larger distances between households and healthcare providers and the continuation of traditional healthcare practices.

Besides geographical location being a determining factor for the vaccination of households, it is also an important factor for the provision of vaccinations (Canavan et al., 2014). Different vaccines have different needs in order to ensure their preservability (Bloom et al., 2005). As some healthcare providers are located in difficult to access, rural areas, difficulties in the supply chain can arise, preventing parents from being able to vaccinate their children. Vaccines often require good roads and reliable modes of transport due to their composition and expiration date. Additionally, many vaccines need functioning freezers and refrigerators during transport, which simultaneously requires a stable supply of energy. These requirements are often not met due to the poor infrastructure in many rural areas, limiting healthcare providers from setting up vaccination campaigns in those parts of developing countries.

### 2.3.2. Maternal Education

Sambala et al. (2018) and Calhoun et al. (2014) argued that inequalities in maternal educational attainment contribute to differences in the vaccination rate. The same can be argued for paternal education, but the effect of maternal education tends to be larger as Arsenault et al. (2017b) showed in their study on 45 countries who are supported by the Global Alliance for Vaccines and Immunizations. Since mothers are the primary caregivers, children of highly educated mothers are 1.45 times as likely to get vaccinated compared to the least educated mothers, compared to 1.37 times in the case of paternal education.

Children of uneducated mothers, and to a lesser extent uneducated fathers, thus have a significantly higher risk of not being fully vaccinated. This is likely due to the fact that most uneducated mothers are illiterate and are therefore not able to grasp the benefits of complete and timely vaccination (Bugvi et al., 2014). In contrast, educated mothers are more likely to remember dates and are more likely to interact freely with healthcare workers, fostering the uptake of vaccinations (Dasgupta et al., 2018). This shows that there is a direct effect of education, lessons learned already improve the vaccination coverage, and that there is an indirect effect, as educated mothers are better able to comprehend health-related information (Bondy et al., 2009). Besides, poorly educated mothers are more likely to perform unskilled work, leading to lower wages. This also makes it harder for them to find the time and resources to go to healthcare providers, reducing the vaccination coverage among children of poorly educated mothers. Moreover, highly educated mothers are more open to new and modern ideas and they have more confidence in strangers, in this case, healthcare professionals, which boosts the vaccination rate of children of these mothers as well.

Onsomu et al. (2015) showed that Kenyan women who went through primary and secondary education, and college or university were around 2.5 times as likely to vaccinate their children against polio, measles, and DPT and even 5.25 times as likely to immunise them against tuberculosis compared to mothers who only went through primary and secondary education. Simultaneously, Uthman et al. (2018) showed that children from sub-Saharan African mothers with no or only primary education have a 14% higher chance of having a missed opportunities for vaccination compared to children from mothers who did go through either secondary or higher education. When examining the influence of different levels of education, Vikram et al. (2012) found that the relationship between maternal education and the rate of childhood immunisation in India was positive and that this effect was the highest among mothers who went through primary education compared to mothers who had no educational background. This effect remained positive but the additional increase became smaller between each subjacent higher level of maternal education.

The level of maternal education also plays a role in understanding messages transmitted through mass media (Jung et al., 2015; Zeitlyn et al., 1992). Highly educated mothers are more likely to grasp the benefits of vaccination compared to lower educated mothers, leading to a pro-vaccination attitude combined with positive health-seeking behaviour. Higher household wealth, as for example shown by possessing a radio, television, and/or computer among others, thus enables mothers to be aware of vaccination strategies in their region while mass media simultaneously gives them access to information on timely and complete vaccination. Higher educated mothers have the additional advantage of better being able to grasp the aforementioned advantages and information on vaccination, leading to a higher vaccination coverage of children from highly educated, wealthier mothers (Jamil et al., 1999).

### 2.3.3. Household Size

Additionally, a wide array of studies showed that a higher number of children per household leads to an increase in the chance of the children not being fully immunised (Akmatov & Mikołajczyk, 2012; Sheik et al., 2018; Uthman et al., 2018). Uthman et al. (2018) found that for every additional child, the chance of a child being unimmunised increased. Rossi (2015) showed that in Zimbabwe, children living in households with up to three children have a 68.4% chance of being fully vaccinated compared to 55.6% of the children in households with four or more children. Calhoun et al. (2014) found that children who are not the firstborn, have a lower chance of becoming fully vaccinated and that this effect increases substantially in size when a household consists of three or more children. In the Philippines, Bondy et al. (2009)

furthermore showed that this effect is larger when there are more children within the age bracket of 0 to 5 years old compared to households in which only one child is aged within this age bracket.

Various explanations for this relationship have been coined. Sheik et al. (2018) argued that the priority for participating in immunisation practices decreases when households experience food and resource shortages, which is more likely in larger households. Besides, a larger household increases the burden of childcare which is mostly the responsibility of women in developing countries. This diminishes the time and attention spent on each child, leading to lower immunisation rates (Antai, 2009). At the same time, mothers with multiple children are more likely to synchronise visits to healthcare centres even though this might hinder the immunisation of some of these children as these visits do not correspond with recommended vaccination schedules (Calhoun et al., 2014). Hence, having more children makes it more difficult to provide healthcare services, possibly due to financial constraints as well as the inability to leave the house as other family members need to be taken care of.

#### 2.3.4. Power Dynamics

The power dynamics in the relation between parents also play a role in the vaccination coverage (Bangura et al., 2020; Samuelsson, 2020). In many developing countries, household decisions are still determined through existing hierarchies based upon an interplay between gender roles and generational power (Vikram et al., 2012). Many sub-Saharan African countries consist of patriarchal societies in which female autonomy is constrained. This negatively influences health outcomes since women are the primary caretaker of their families. Not only do most countries consist of patriarchal societies, but the elderly also have an important role to play in family dynamics and decisions. As older generations are less familiar with modern science and have a higher belief in traditional health practices, the need for timely and complete vaccination is not or less recognised. Due to the higher importance of older generations within families, maternal autonomy is restricted, thus preventing children from being vaccinated. Besides, women's mobility outside their hometowns is often limited which further restricts their ability to make decisions about healthcare. Antai (2009) showed that Indian women who have less autonomy in making household decisions, measured through lacking autonomy in decisions on their health, visiting relatives, making large purchases, and purchasing daily needs, had a substantially larger number of not-fully immunised children. Simultaneously, Samuelsson (2020) argued that a larger spousal age gap in patriarchal societies indicates less female autonomy and thus limited maternal decision-making power. This explains their finding that children in households with a larger than average age gap are less likely to be fully vaccinated.

However, women do have the possibility to increase their autonomy and therefore change the power dynamics within their households. Vikram et al. (2012) argued that higher educational attainment enables women to take on a more active and assertive role, increasing their autonomy within their households and in society. Arsenault et al. (2017a) also argued that educated mothers have greater decision-making power and autonomy which combined with the better knowledge of healthcare practices and higher social status, leads to a higher chance of their children becoming vaccinated.

### 2.4. Hypotheses

Based on previous studies, it is expected that higher household wealth will influence the vaccination rate positively. It is also expected that living in rural areas, larger household size, and having less female autonomy will correspond to a negative relation between the aforementioned variables and the vaccination rate while this effect is expected to be positive for maternal educational attainment. Furthermore, it is expected that there is an interaction effect between maternal education and power dynamics as females with higher educational attainment are more likely to have more autonomy which further boosts the vaccination rate of their children. An additional interaction effect is expected between household wealth and maternal education, as higher household wealth is likely to indicate that the household has access to mass media, and higher educational attainment enhances the comprehension of information provided by the same mass media on the benefits of vaccination. Thus, mothers with a higher level of education living in a richer household are expected to have more children that are fully vaccinated. Finally, an interaction between household wealth and urbanisation is expected. Since wealthier households, as well as households in urban areas, are expected to have higher vaccination rates, it is expected that this effect is higher for wealthier households in urban areas.

## 3. Methodology

This chapter is divided into three parts. The first part will discuss the data sources used in this study, the Global Data Lab and the World Bank. The second part will look more closely at the method while the third part will examine the variables used.

## 3.1. Data

This study is based on data from the Area Database from the Global Data Lab (www.globaldatalab.org) and the World Bank (www.data.worldbank.org). The Global Data Lab is a database consisting of socio-economic, health, and demographic indicators derived from representative large-scale household surveys like the DHS and the UNICEF MICS surveys conducted in developing countries. The advantage of the Global Data Lab is that the data is comparable across time and space whereas this is not the case for surveys like the DHS and the UNICEF MICS surveys as the questions asked differ per country and year of analysis. In these surveys, the socio-economic, demographic, and health situations in developing countries are examined through household surveys which are representative of entire countries and regions. The Global Data Lab combines the findings of the DHS, UNICEF MICS, and many other surveys in one large, comparable database by using the same criteria for each year and country. Currently, the Global Data Lab provides data for 131 countries, 1483 sub-national regions, 38.6 million persons, and 8.7 million households throughout the developing world.

According to the World Bank, sub-Saharan Africa consists of 48 countries, but this study is done on the 37 sub-Saharan Africa countries for which data is available. The Seychelles are not included in the Global Data Lab database whereas data on Botswana, Cabo Verde, Central African Republic, Equatorial Guinea, Guinea-Bissau, Mauritius, Sao Tome and Principe, Somalia, South Sudan, and Sudan is lacking for the dependent variable, *vaccination rate*. In order to take the different levels of development within these countries into account, regional data is used beside national data. Hence, in this study, data of 422 regions in 37 sub-Saharan Africa countries for the period 2000-2018 is extracted from the Global Data Lab and the World Bank. Appendix A and B consist of a list of the countries, number of regions, and corresponding years included and excluded respectively. This period has been selected since 2000 is the earliest year on which data is available for *health expenditure* while 2018 is the latest year on which data on the dependent variable is available in the Global Data Lab. For each country, the years in which the aforementioned surveys are conducted are taken into account while intervening years are approximated through linear interpolation.

## 3.2. Method

In this study, multilevel analyses are conducted to estimate the effect between the vaccination rate and household wealth. As discussed in the previous section, the data used in this study has a hierarchical structure as the data on the regional level is nested within different countries. The choice for multilevel analyses has been made since the vaccination rate does not only differ between countries but also differs substantially between various regions within countries. Hence, single-level analyses, like OLS, would lead to problems as regions across different countries vary to a larger extent compared to regions within a certain country. As a result, the residuals would no longer be independent which leads to underestimated standard errors and overestimated statistical significance (Snijders & Bosker, 2011). The multilevel model is able to correct for clustering of regions within countries whereas it is also able to take into account the determinants of the vaccination rate at both levels.

The models examined in this study contain two levels. The first level is the regional level in which data is based on the aggregate of individuals responses. The second level is the national level, which controls for the role of political and socio-economic contextual factors at the national level. The second level is added since the vaccination rate depends on national characteristics in addition to the regional characteristics. In this study, random intercept and random coefficient multilevel analyses are conducted. The random intercept analyses are used to check whether there is any variation among countries in terms of their vaccination rate while the second model is used to check whether the effect size differs for the countries as well. It is expected that this is the case since the countries in sub-Saharan Africa vary substantially in their level of development.

## 3.3. Variables

### 3.3.1. Dependent Variable

As mentioned in the Introduction, this study examines the relationship between the vaccination rate and household wealth. In order to do so, the vaccination rate of children aged 1 is used as the dependent variable. The Global Data Lab offers various indicators to measure this, respectively percentage of children aged 1 with BCG, DTP1, DTP2, DTP3, and measles. This study uses the percentage of children aged 1 with DTP3, with a range from 0 to 100%, as indicator for the *vaccination rate*. DTP3 coverage is taken as the standard measure of the vaccination rate by both the World Health Organization and Global Alliance for Vaccines and Immunizations since it reflects the strength of immunisation- and health systems (Arsenault, 2017a; GAVI, n.d.; Vanderende et al., 2018). One reason for the preference for DTP3 is that in order to get the DTP3 vaccine, three contact moments with healthcare providers at specific points in time are needed (GAVI, n.d.). Another reason is that DTP vaccines are given through routine national immunisation programmes instead of vaccination campaigns, thus reflecting a countries health system. By using the vaccination rate of DTP3, this study simultaneously follows various earlier studies (Arsenault et al., 2017b; Restrepo-Mendéz et al., 2016).

### 3.3.2. Independent Variable

The main independent variable is a proxy for *household wealth*, the mean International Wealth Index score of the region, derived from the Area Database from the Global Data Lab. The International Wealth Index is the first comparable sub-national asset-based wealth index with data covering the entire developing world across time (Smits & Steendijk, 2015). Other studies use wealth indices derived from the DHS and UNICEF MICS surveys; however, these are not directly comparable across place and time since questionnaires differ over time and between countries. Therefore, the indices constructed using these surveys differ in terms of their composition. The International Wealth Index solves this by using the same criteria for the index in each year and country, making it comparable across time and place.

The International Wealth Index is constructed by examining the possession of consumer durables, access to basic services, and housing characteristics derived from household surveys. The International Wealth Index ranges from 0 to 100 with 0 representing a household with no consumer durables, the lowest possible quality of housing, and no access to basic services while 100 represents a household with all consumer durables, the highest quality of housing characteristics, and access to all basic services. The International Wealth Index score is calculated by using the square root of a country's population which ensures that the population sizes of larger and smaller countries are both taken into account while it also ensures that larger countries do not have a too large influence on the International Wealth Index. Like many other asset-based wealth indices, the International Wealth Index uses principal component analysis to compute the asset weights. Because of this, the asset weight reflects the extent to which a household that owns a certain asset also owns another asset. The International Wealth Index thus ensures that more expensive assets do not necessarily have a higher weight compared to cheaper assets but that it depends on the relative position compared to other assets.

The International Wealth Index has a high correlation with other measures of welfare and poverty, like the Human Development Index, life expectancy, and the Poverty Headcount Ratio's, showing that the International Wealth Index performs well and is a good alternative. The International Wealth Index is thus a useful asset-based wealth index that is comparable among countries and points in time, making it a good proxy for household wealth in this study. It is hypothesised that there is a positive effect between the *vaccination rate* and *household wealth* as explained in Chapter 2.

### 3.3.3. Regional Control Variables

As discussed in the Theoretical Framework, various other variables are important determinants of vaccination coverage, therefore these variables will be added as control variables. The first control variable is *urbanisation*, measured through the percentage of the population in urban areas, ranging from 0 to 100%. Previous studies indicated that the immunisation rate is higher for children in urban areas as health facilities are more easily accessible, therefore a positive relation is expected (Adedokun et al., 2017; Favin et al., 2012). The second control variable is *maternal education*, measured through the mean years of education of women aged 20+. In the literature, a distinction can be seen between studies using the completion of primary, secondary, and tertiary education as a measure of educational attainment and others using the mean years of education completed (Breiman et al., 2004; Calhoun et al., 2014; Onsomu et al., 2015). Since both measures showed that higher educational attainment leads to higher vaccination rates and since the Global Data Lab only offers data on the mean years of education, the latter is used. Earlier studies indicated that the vaccination rate of children was higher among higher educated mothers, therefore, a positive relationship is expected between *maternal education* and the *vaccination rate*. The third variable is *power dynamics*, measured through the mean age difference between partners (husband-wife). Samuelsson (2020) argued that a large age difference between partners is common in patriarchal societies, which corresponds to less female autonomy. As mothers are the primary caretakers within households, less autonomy results in a lower vaccination rate. Hence, a negative relationship is expected. The fourth is *household size*, measured through the average household size. Larger households are more likely to experience food shortages and lacking resources. As fulfilling these needs are the primary concerns of families, participating in immunisation practices becomes less important (Sheikh et al., 2018). It is thus expected that *household size* negatively influences the *vaccination rate*. Since many sub-Saharan Africa households consist of a family living with either maternal or paternal grandparents in the same household, *living with grandparents*, measured through the percentage of households where couples live with their parents, is taken into account (Zimmer & Dayton, 2005). This is calculated by summing up the percentage of households where couples live with the husband's parents and the percentage of households where couples live with the wives' parents. Sear and Mace (2008) argued that the presence of grandparents within a household leads to improved survival rates of children. This is partially due to the fact that the grandparents are able to take care of their grandchildren while the parents are able to spend time on other affairs, among which healthcare visits with vaccine-eligible children. Hence, the presence of grandparents within the household is likely to have a positive effect on the vaccination rate. The aforementioned variables are all derived from the Global Data Lab and are measured at the regional level.

### 3.3.4. National Control Variables

Besides the variables at the regional level, *health expenditure* is used as a national variable as done by Arsenault et al. (2017a) and Nicholas et al. (2016). This is measured through the current health expenditure per capita, adjusted for PPP in the current international dollar derived from the World Bank. Nicholas et al. (2016) showed that an increase in health expenditure leads to improvements in various health outcomes, among which reduced child- and maternal mortality and increased vaccination rates. Therefore, a positive relationship is expected between *health expenditure* and the *vaccination rate*. Additionally, *corruption*, measured through the score of a country on the Corruption Perceptions Index (CPI), has been included to account for possible corruption. Corruption could negatively influence the vaccination rate as healthcare spending could end up in the wrong hands (Hsiao et al., 2019; Novigon, 2015). The CPI measures ‘’the overall extent of corruption (frequency and/or size of bribes) in the public or political sectors’’ (Lambsdorff, 2004). The scores on the CPI range from 1 to 10, with 1 indicating that a country is highly corrupt and 10 indicating that a country is very clean in terms of corruption. Data on *corruption* is derived from the World Bank. Since a higher score on the CPI equals less corruption, it is hypothesised that the relationship between *corruption* and the *vaccination rate* is positive.

### 3.3.5. Interaction Variables

Additionally, three interaction variables are tested. The first is between *household wealth* and *maternal education*, the second is between *maternal education* and *power dynamics*, and the third is between *household wealth* and *urbanisation*. It is hypothesised that all interactions are positively related to the vaccination rate. Concerning the first interaction effect between *household wealth* and *maternal education,* it is expected that the effect of maternal education on the vaccination rate is stronger in wealthier households as these mothers have the capability to understand the benefits of vaccination while they are also more likely to be able to access information through media campaigns, and are more likely to participate in health-seeking behaviour (Agopian et al., 2020). As explained in the Theoretical Framework, it is expected that higher educational attainment leads to more female autonomy while it also leads to a better understanding of health-related information. Hence, highly educated mothers are more likely to have more autonomy, enabling them to make more decisions, ultimately leading them to vaccinate their children. Therefore, it is expected that the effect of maternal education on the vaccination rate is stronger in households with a lower spousal age difference. Finally, households scoring higher in terms of their wealth are often located in urban areas (Armstrong et al., 2008). As discussed earlier, urban areas are more likely to have healthcare providers leading to higher vaccination rates in these areas. Children in wealthier households are also more likely to be vaccinated. Hence, it is expected that the effect of urbanisation on the vaccination rate is stronger for wealthier households.

# 4. Results

## 4.1. Descriptive Statistics

Table 1 shows the descriptive statistics for the variables used in this study. As mentioned in the previous chapter, the dataset consists of 422 regions within 37 countries for the period 2000 until 2018. Because of this, there are 8,904 possible observations but due to data constraints, only the 4,926 data points for which data on the dependent variable was available are taken into account. These data constraints arose as the availability of data for the percentage of children aged 1 with DTP3 was limited for certain countries and years as Appendix A and B show. A few countries had missing data points for *household size*, *urbanisation*, and *health expenditure* in one or more of the years included. For these points, the dummy variable adjustment method has been used. Hence, the missing data points were replaced by the mean of the variable which is based on the data for the survey years of that region that were available. This resulted in 4,926 observations for all variables. Through partial plots, the data has been examined for outliers. The variables *household size* and *power dynamics* both had outliers which have been replaced by the mean of that variable.

Table 1
*Descriptive Statistics*

| VARIABLES | (1)<br>N | (2)<br>mean | (3)<br>sd | (4)<br>min | (5)<br>max |
|---|---|---|---|---|---|
| Vaccination rate | 4,926 | 64.96 | 24.52 | 0 | 100 |
| Household wealth | 4,926 | 29.80 | 15.48 | 2.84 | 86.30 |
| Urbanisation | 4,926 | 31.73 | 26.03 | 0 | 100 |
| Maternal education | 4,926 | 3.97 | 2.57 | 0.08 | 11 |
| Household size | 4,926 | 6.96 | 1.84 | 4.09 | 17.70 |
| Power dynamics | 4,926 | 7.88 | 2.26 | 2.40 | 14.30 |
| Living with grandparents | 4,926 | 9.35 | 7.40 | 0.61 | 57.22 |
| Health expenditure | 4,926 | 249.10 | 792.20 | 11.42 | 8,431 |
| Corruption | 4,926 | 2.86 | 0.82 | 1 | 5.70 |

The dependent variable *vaccination rate*, measured through the percentage of children aged 1 with DTP3, has a mean of 64.96% and a standard deviation of 24.52%. It ranges from 0% in four Nigerian regions to 100% in six regions throughout Senegal and Tanzania. The explanatory variable *household wealth*, measured by the International Wealth Index, has a mean of 29.80 and a standard deviation of 15.48. It ranges from 2.84 in Amhara, Ethiopia, to 86.30 in Western Cape, South Africa.

The first regional-level control variable is *urbanisation*, as measured by the percentage of the population living in urban areas, which has a mean of 31.73% and a standard deviation of 26.03%. It ranges from 0 to 100% with 0% of the population living in urban areas in 13 regions throughout six countries and 100% in 24 regions throughout 21 countries. *Maternal education*, measured through the average years of education followed by women aged 20+, has a mean of 3.97 years and a standard deviation of 2.57 years. It ranges from 0.08 years in one region in Chad to 11 years for two regions in both Kenya and Nigeria. *Household size*, as measured by the average household size, has a mean of 6.96 household members and a standard deviation of 1.84. It ranges from 4.09 members in Nairobi, Kenya, to 17.70 members in Tambacounda, Senegal. *Power dynamics*, measured by the age difference between spouses, has a mean of 7.88 years and a standard deviation of 2.26 years. It ranges from 2.40 years in Hardap, Namibia, to 14.30 in Labe, Guinea. *Living with grandparents,* as measured by the percentage of spouses living with either the husbands and/or wives parents, has a mean of 9.35% and a standard deviation of 7.40%. It ranges from 0.61% in East (Cankuzo, Rutana, Ruyigi), Burundi, to 57.22% in Louga, Senegal.

The first country-level control variable is *health expenditure*, as measured by the national current health expenditure per capita, adjusted for PPP in the current international dollar, which has a mean of 249.10 dollars and a standard deviation of 792.20 dollars. It ranges from 11.42 dollars in Mozambique to 8,431 dollars in Liberia. Finally, *corruption*, as measured by the Corruption Perception Index, has a mean of 2.86 and a standard deviation of 0.82. It ranges from 1 in Nigeria to 5.70 in Namibia.

Before conducting a correlation analysis, all variables have been checked for normal distribution. All variables were more or less normally distributed except for *health expenditure* which was extremely skewed to the right. Because of this, the variable *health expenditure* has been transformed to the log function in further analyses.

Table 2
*Correlation Matrix*

| Variables | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| (1) Vaccination rate | 1.00 | | | | |
| (2) Household wealth | 0.25*** | 1.00 | | | |
| (3) Urbanisation | 0.15*** | 0.76*** | 1.00 | | |
| (4) Maternal education | 0.38*** | 0.69*** | 0.53*** | 1.00 | |
| (5) Household size | -0.13*** | -0.08*** | -0.10*** | -0.49*** | 1.00 |
| (6) Power dynamics | -0.41*** | -0.14*** | -0.10*** | -0.55*** | 0.58*** |
| (7) Living with grandparents | 0.06*** | -0.03* | -0.12*** | -0.34*** | 0.77*** |
| (8) Health expenditure | 0.08*** | 0.46*** | 0.21*** | 0.43*** | -0.11*** |
| (9) Corruption | 0.43*** | 0.29*** | 0.08*** | 0.21*** | 0.02 |

**** p<0.01, ** p<0.05, * p<0.1*

Table 2 Continued

| Variables | (6) | (7) | (8) | (9) |
|---|---|---|---|---|
| (1) Vaccination rate | | | | |
| (2) Household wealth | | | | |
| (3) Urbanisation | | | | |
| (4) Maternal education | | | | |
| (5) Household size | | | | |
| (6) Power dynamics | 1.00 | | | |
| (7) Living with grandparents | 0.46*** | 1.00 | | |
| (8) Health expenditure | -0.26*** | -0.07*** | 1.00 | |
| (9) Corruption | -0.37*** | 0.06*** | 0.43*** | 1.00 |

**** p<0.01, ** p<0.05, * p<0.1*

Table 2 present the correlation coefficients and corresponding significance levels. All correlations are highly significant except for the correlation between *corruption* and *household size* which is significant at the 10% level. The correlation coefficients between the *vaccination rate* and the independent variables are all in the hypothesised direction. The strongest correlation coefficients are between *household size* and *living with grandparents* (0.77) and *household wealth* and *urbanisation* (0.76). When one lives with one's grandparents, there are automatically two additional household members, which explains the first correlation while richer sub-Saharan African households tend to be located in urban areas as Sahn and Stifel (2003) show, thus explaining the latter correlation. The correlations between the *vaccination rate* and the independent variables are 0.43 at the highest. Hence, these correlations are rather weak but since they are significant, further analyses can be conducted. Since various correlations are rather high, a variance inflation factor analysis has been conducted to check whether the data suffers from multicollinearity. The results for the multicollinearity test can be found in Appendix C. The variance inflation factor is 2.22 which is below the critical value of 5. Hence, the data does not suffer from multicollinearity and further analyses can be conducted.

## 4.2. Multivariate Analysis

Through post-estimation tests, the assumptions for the multilevel model have been checked. First, the residuals of the models without interactions (3) have been calculated. To check whether there is a linear relationship between the dependent and independent variables, the independent variables have been plotted against the residuals which showed that there is linearity. Next, a histogram of the level 1 residuals has been made to check whether the residuals are normally distributed which was confirmed. To check whether the level 1 residuals were homoscedastic, a scatterplot of the residuals and the projected values was created which confirmed that the level 1 residuals were homoscedastic. The final assumption of independence of observations is violated by design in a multilevel model. However, the correlation between the level 1 and level 2 residuals has been checked which showed that these were uncorrelated.

First, the random intercept model has been examined which assumes that there are random differences between the countries. Therefore, each country is likely to have a different intercept whereas it is expected that the effect size is the same for each country. The results for the random intercept analyses can be found in Table 3.

Table 3

*Multilevel Random Intercept Regression Output*

| | (1) Random Intercept | (2) Model (1) incl. regional control variables | (3) Model (2) incl. national control variables | (4) Model (3) incl. interaction terms |
|---|---|---|---|---|
| Household wealth | $0.68^{***}$ (0.018) | $0.25^{***}$ (0.034) | $0.10^{**}$ (0.035) | $0.22^{***}$ (0.035) |
| Urbanisation | | $-0.10^{***}$ (0.014) | $-0.05^{***}$ (0.014) | 0.02 (0.015) |
| Maternal education | | $4.59^{***}$ (0.224) | $4.69^{***}$ (0.221) | $4.04^{***}$ (0.225) |
| Household size | | $-2.00^{***}$ (0.253) | $-2.21^{***}$ (0.250) | $-2.72^{***}$ (0.245) |
| Power dynamics | | $-1.81^{***}$ (0.220) | $-1.50^{***}$ (0.219) | $-1.05^{***}$ (0.217) |
| Living with grandparents | | $0.60^{***}$ (0.053) | $0.65^{***}$ (0.052) | $0.69^{***}$ (0.051) |
| Health expenditure | | | $4.45^{***}$ (0.748) | $4.19^{***}$ (0.730) |
| Corruption | | | $3.77^{***}$ (0.517) | $3.47^{***}$ (0.500) |

Table 3 Continued

| | (1)<br>Random Intercept | (2)<br>Model (1) incl. regional control variables | (3)<br>Model (2) incl. national control variables | (4)<br>Model (3) incl. interaction terms |
|---|---|---|---|---|
| Household wealth x maternal education | | | | $-0.02^{**}$<br>(0.008) |
| Maternal education x power dynamics | | | | $0.61^{***}$<br>(0.055) |
| Household wealth x urbanisation | | | | $-0.003^{***}$<br>(0.001) |
| Constant | $47.36^{***}$<br>(3.106) | $68.59^{***}$<br>(3.866) | $37.34^{***}$<br>(5.182) | $39.72^{***}$<br>(5.085) |
| Observations | 4926 | 4926 | 4926 | 4926 |
| Log lik | -20328.1 | -19777.5 | -19704.0 | -19534.9 |
| Intraclass cor | 0.612 | 0.658 | 0.701 | 0.708 |

Standard errors in parentheses
$^{*}\ p < 0.05$, $^{**}\ p < 0.01$, $^{***}\ p < 0.001$
Note. Model (4) uses centred variables for household wealth, maternal education, power dynamics, and urbanisation in the interaction terms.

The coefficient between the dependent variable *vaccination rate* and the main explanatory variable *household wealth* is in the expected positive direction and is significant in all models. What stands out in these analyses, is the negative and significant coefficient for *urbanisation* in models (2) and (3) which is not in line with the hypothesised positive relation. In model (4) the interactions have been added which are all significant. As a result, the coefficient for *urbanisation* turned positive but is no longer significant. This is potentially due to the fact that the coefficient for *urbanisation* only holds for the centred value of *household wealth* even though the value of many observations of *household wealth* diverges from this centred value. This thus shows that *urbanisation* has no statistically significant effect on its own when *household wealth* takes on the centred value. However, the interaction term that includes *urbanisation* is significant. The interaction between *maternal education* and *power dynamics* is in the expected positive direction. However, the interactions between *household wealth* and *maternal education* and *household wealth* and *urbanisation* are negative whereas a positive coefficient was hypothesised. Possible explanations for these findings, as well as for the negative relation between the *vaccination rate* and *urbanisation*, will be discussed in Chapter 5.

For each additional model the log-likelihood ratio increases, confirming that the more extensive models have a better fit. The intraclass correlation increases from 61.2% to 70.8%, showing that in model (4) 70.8% of the variance can be explained through country differences whereas 29.2% of the variance can be explained through regional differences.

The random intercept model assumes that the intercept differs between countries whereas the effect size is the same for each country. However, due to the large contextual differences between the countries in sub-Saharan Africa, it is expected that the effect sizes differ as well. Hence, it is expected that the multilevel random coefficient models are better in explaining the relation between the vaccination rate and household wealth. Table 4 present the results of these random coefficient analyses.

Table 4

*Multilevel Random Coefficient Regression Output*

| | (1) Random Coefficient | (2) Model (1) incl. regional control variables | (3) Model (2) incl. national control variables | (4) Model (3) incl. interaction terms |
|---|---|---|---|---|
| Household wealth | $0.63^{***}$ (0.087) | $0.40^{***}$ (0.093) | $0.21^{*}$ (0.096) | $0.23^{**}$ (0.089) |
| Urbanisation | | $-0.09^{***}$ (0.014) | $-0.03^{*}$ (0.014) | 0.01 (0.016) |
| Maternal education | | $2.98^{***}$ (0.243) | $3.33^{***}$ (0.241) | $3.29^{***}$ (0.241) |
| Household size | | $-2.66^{***}$ (0.248) | $-2.80^{***}$ (0.245) | $-2.71^{***}$ (0.241) |
| Power dynamics | | $-2.26^{***}$ (0.220) | $-1.87^{***}$ (0.218) | $-1.19^{***}$ (0.226) |
| Living with grandparents | | $0.55^{***}$ (0.052) | $0.60^{***}$ (0.051) | $0.57^{***}$ (0.050) |
| Health expenditure | | | $5.02^{***}$ (0.735) | $4.85^{***}$ (0.726) |
| Corruption | | | $3.44^{***}$ (0.496) | $3.68^{***}$ (0.489) |
| Household wealth x maternal education | | | | $-0.06^{***}$ (0.011) |
| Maternal education x power dynamics | | | | $0.49^{***}$ (0.067) |
| Household wealth x urbanisation | | | | -0.0003 (0.001) |
| Constant | $50.89^{***}$ (4.321) | $80.89^{***}$ (4.708) | $46.69^{***}$ (5.782) | $41.29^{***}$ (5.979) |

Table 4 Continued

| | (1)<br>Random Coefficient | (2)<br>Model (1) incl. regional control variables | (3)<br>Model (2) incl. national control variables | (4)<br>Model (3) incl. interaction terms |
|---|---|---|---|---|
| Observations | 4926 | 4926 | 4926 | 4926 |
| Log lik | -19817.1 | -19447.5 | -19368.4 | -19289.9 |
| Intraclass cor | 0.794 | 0.797 | 0.811 | 0.836 |

Standard errors in parentheses
$^{*}$ $p < 0.05$, $^{**}$ $p < 0.01$, $^{***}$ $p < 0.001$
Note. Model (4) uses centred variables for household wealth, maternal education, power dynamics, and urbanisation in the interaction terms.

The first model (1) shows that the coefficient between the dependent variable *vaccination rate* and the main explanatory variable *household wealth* is highly significant and in the expected positive direction. Hence, the vaccination rate is higher when household wealth is higher. In the second model (2), the regional control variables are added. All coefficients are significant and in the expected direction, except for *urbanisation* which is negative instead of the hypothesised positive which will be discussed in Chapter 5. So, model (2) shows that the vaccination rate is higher when the mother has gone to school longer and when either or both maternal and paternal grandparents live in the same household while the vaccination rate is lower for children living in urban areas, living in larger households, and when they have parents with a larger age difference. In the third model (3), the national control variables are added. The significance levels for *household wealth* and *urbanisation* have decreased compared to the previous model but are still significant at the 5% level. The coefficients for *health expenditure* and *corruption* are also in the hypothesised direction, the vaccination rate increases when health expenditure is higher and when a country scores higher on the Corruption Perceptions Index. Hence, the coefficients for the variables in model (1) until (3) are in line with the literature and the hypotheses, except for *urbanisation*. The fourth model (4) adds the interaction terms. The coefficient for *household wealth* increases in terms of significance to the 1% level while the coefficient becomes more positive compared to model (3). *Urbanisation*, however, is no longer significant. The interaction term between *household wealth* and *maternal education* is significant, but not in the expected positive direction. The interaction term for *maternal education* and *power dynamics* is also significant and is in the expected direction. The final interaction term between *household wealth* and *urbanisation* is not significant whereas this interaction was negative and significant in the random intercept model. Possible explanations for the outcomes of the interactions between *household wealth* and *maternal education* and *household wealth* and *urbanisation* will be discussed in Chapter 5.

The log-likelihood ratio increases for each additional model thus showing that model (4) has the best fit. The log-likelihood ratio is also higher for each model compared to the respective model in the random intercept model which shows that the random coefficient model has a better fit. The intraclass correlation increases from 79.4% in model (1) to 83.6% in model (4). Hence, in model (4), 83.6% of the variance can be explained through country differences whereas 16.4% of the variance can be explained through regional differences. To conclude, when examining the relationship between the *vaccination rate* and the main explanatory variable, *household wealth*, the random coefficient models show that the coefficient for *household wealth* is positive, even after controlling for contextual factors, which is in line with the main hypothesis and the literature.

### 4.3. Robustness Checks

In order to ensure the robustness of the aforementioned results, two robustness checks have been conducted. The first robustness check used a different measure for the dependent variable *vaccination rate*. Instead of the percentage of children aged 1 vaccinated with DTP3, the percentage of children aged 1 vaccinated with measles is used. This is in line with the UN Office for the Coordination of Humanitarian Affairs (UN OCHA) which states that besides DTP3, measles is often used as a proxy for vaccination coverage since the corresponding vaccination rate is lower compared to DTP3 in many countries (n.d.). As a result of the higher DTP3 vaccination rates, the corresponding estimations could be overestimated. Hence, using the vaccination coverage of measles instead of DTP3 ensures that overestimation of the coefficients and standard errors is avoided. Because of this, *vaccination rate* has a mean of 69.76%, a standard deviation of 20.32%, and it ranges from 0 until 100%. The descriptive statistics and the results for this robustness check can be found in Appendix D, Table 8 and 9.

When comparing the outcomes of these models to the random coefficient models in Table 4, most coefficients remained in the same direction and remained significant. The only difference is that *corruption* is no longer significant in model (4) while the coefficient turned negative and became less significant in model (3). Dietrich (2011) argued that corrupt governments have a larger incentive to comply with objectives set by the donors of foreign aid in the health sector as compliance to health-related objectives is often cheaper compared to other sectors. This can possibly explain why more corruption leads to a higher vaccination rate. Overall, the main coefficients between the *vaccination rate* and *household wealth* remain positive and significant in all models.

The second robustness check is done with the same data as is used in the analyses done in Section 4.1. and 4.2. However, the data for Nigeria has been omitted from the data set as Nigeria made up 703 out of the 4,926 observations (14.27%). As a result, the analyses excluding Nigeria were conducting using 4,223 observations. Compared to the initial descriptive statistics, the mean of the *vaccination rate* increased to 68.60%, while the standard deviation increased to 22.12%. The vaccination rate range ranges from 1.10 to 100% instead of 0 to 100%. The descriptive statistics and the results for this robustness check can be found in Appendix E, Table 10 and 11.

When comparing these models to the random coefficient models in Table 4, most coefficients remained significant and in the same direction. The differences are that *urbanisation* turned significant in model (4) and that the interaction term between *household wealth* and *urbanisation* became significant with a negative coefficient. Also in this robustness check, the main coefficients between the *vaccination rate* and *household wealth* remain positive and significant in all models.

# 5. Discussion

## 5.1. Discussion

Despite vast medical advancements over the past few decades, a large number of people die prematurely each year due to vaccine-preventable diseases (Vanderslott et al., 2013). Vaccines are the solution for decreasing the number of these premature deaths. Various studies have indicated that household wealth is an important predictor of the vaccination rate. Through various ways, household wealth is related to the vaccination rate. Among others, poor health-seeking behaviour among poorer households, user fees for vaccinations, and parental accessibility to media have been found to have a profound impact on the vaccination rate. The aim of this study was to find out what the relationship is between the International Wealth Index and the vaccination rate as well as between the vaccination rate and various other socio-economic outcomes. As mentioned earlier, the International Wealth Index is the first comparable sub-national asset-based wealth index with data on the entire developing world over time. This study is one of the first to use the International Wealth Index for this specific topic and therefore contributes to the existing literature examining the relationship between household wealth and the vaccination rate.

This study used a sample of 422 regions within 37 sub-Saharan African countries over the period 2000-2018. The results indicated that the relationship between the *vaccination rate* and *household wealth* is positive and highly significant in all models, the average vaccination rate is thus significantly higher in regions where the International Wealth Index score is higher compared to regions scoring lower on the International Wealth Index. The literature discussed in Chapter 2 also found a positive relationship between the vaccination rate and household wealth. Richer households are more likely to be able to take time for healthcare-seeking behaviour, they are able to afford transportation, they are able to pay fees for vaccinations if necessary, and they are more likely to have access to media that is able to provide the benefits of, timely, vaccination (Adebowale et al., 2019; Adedokun et al., 2017; Uthman et al., 2018). Hence, the results are in line with the hypothesis formulated in Chapter 2.

Besides the relationship between the *vaccination rate* and *household wealth*, the relation between the *vaccination rate* and various other socio-economic variables has been examined. Most findings were in line with the literature. The results showed that the vaccination rate was higher for mothers with higher educational attainment, children living in smaller households, and in households in which women had more autonomy. These results are also in line with the hypotheses. Higher maternal educational attainment leads to a better understanding of the benefits of complete and timely vaccination, leads to more assertive mothers, while highly educated mothers also have more opportunities to pay visits to healthcare providers (Bondy et al., 2009; Bugvi et al., 2014). Living in smaller households and living with grandparents decreases the burden of childcare for mothers while it also offers mothers the opportunity to spend more time on each child thus making it more likely that a mother opts for vaccinating her children (Antai, 2009; Sheik et al., 2018). Simultaneously, women in developing countries often have less autonomy due to the importance of gender roles and the influence of older generations. Therefore, the decision-making power of mothers is restricted, leading to a lower vaccination rate among the children of mothers with less autonomy. To examine the effect of older generations on the vaccination rate and to control for the fact that many sub-Saharan African households include grandparents, the variable *living with grandparents* was included. In accordance with earlier studies, this effect was positive as grandparents are able to take care of a part of their grandchildren, enabling the parents to visit healthcare providers with the children who are in need of healthcare (Sear & Mace, 2008). Additionally, the results showed that the effect between *household wealth* and *health expenditure* was positive as was expected while it was in the hypothesised negative direction for *household wealth* and *corruption*. Health expenditures are able to improve the healthcare infrastructure while it can also be used to improve information campaigns that foster vaccine uptake (Nicholas et al., 2016). Additionally, lower corruption levels, which in this study equal a higher score on *corruption*, ensure that health expenditures end up at the right places which further stimulates the vaccination rate (Hsiao et al., 2019). The final variable in line with the hypothesis is the interaction term between *maternal education* and *power dynamics* which is positive. The effect of maternal education on the vaccination rate is thus stronger in households in which women have more autonomy, fostering the uptake of vaccinations.

Interestingly, the results showed that *urbanisation* has a negative effect on the *vaccination rate* in models (2) and (3) in both the random intercept as well as the random coefficient analyses whereas a positive relation was expected. Households in rural regions are often located farther away from healthcare services compared to households in urban areas (Adedokun et al., 2017). Besides, many households in rural areas still have limited knowledge of modern medical science which further limits the uptake of vaccines (Onsomu et al., 2015). However, there are also various studies that argue that children in rural areas have higher vaccination rates (Onsomu et al., 2015; Mitchell et al., 2009). Shrivastwa et al. (2015) argued that many urban regions have a vast area of slums and poor neighbourhoods which lack healthcare facilities. Simultaneously, many healthcare programmes are aimed at rural areas which stimulate vaccination rates there while this is to a lesser extent the case in less developed urban areas. This can possibly explain why a negative relation was found between the *vaccination rate* and *urbanisation* in models (2) and (3) whereas the ambiguity among previous studies might also explain why there is no significant relation for *urbanisation* in model (4) when the interaction effects are included.

Additionally, the coefficients of the interactions between *household wealth* and *maternal education* are negative, meaning that the effect of maternal education on the vaccination rate is less strong in wealthier households. This is not as hypothesised and contrary to earlier findings of Agopian et al. (2020). Nonetheless, the finding is in line with a recent trend in Western countries showing that well-educated, affluent parents refuse to vaccinate their children which is argued to arise from an overflow of information (Kahan, 2013; Kien et al., 2017). The interactions between *household wealth* and *urbanisation* are also negative instead of the expected positive, meaning that the effect of urbanisation on the vaccination rate is less strong in wealthier households. A potential explanation for this might be that wealthier households are more likely to have access to transportation and have the ability to take time off for healthcare visits, therefore making it less important for them to live in urban areas as they can easily travel to healthcare providers when living in remote rural areas. Earlier studies did not look into this specific interaction in relation to the vaccination rate, therefore, further examination could potentially clarify and substantiate this outcome as well as for the interaction between *household wealth* and *maternal education.*

When comparing all four models, the effect of *household wealth* decreased when the regional and national control variables are added but increased slightly when the interaction terms are included. This is likely due to the fact that the other variables are partially able to explain the vaccination rate. Additionally, the results showed that there is evidence for geographical clustering of the determinants of the vaccination rate. The results in model (4) of the random coefficient model indicated that 16.40% of the differences in vaccination rate could be attributed to regional-level factors whereas 83.6% of the difference could be attributed to country-level factors. Hence, children living in the same region tend to have a similar vaccination rate. Therefore, public health programmes should not only use national information campaigns but should address the most vulnerable regions in order to improve the vaccination rate in regions where it is needed the most.

## 5.2. Limitations

Although the results are promising and are mostly in line with the hypotheses, the study suffers from various limitations which have to be addressed. Firstly, the causal relationship between the vaccination rate and the independent variables might be two-fold (Boyle et al., 2006). Since the results in this study are drawn from pooled cross-sectional data, no conclusions on the causation between the dependent and independent variables can be made. The results nonetheless provide an interesting, new insight into the relationship between the vaccination rate and various socio-economic variables. Further research could therefore focus on the exact causal relation between the vaccination rate and the independent variables.

Besides, this study only uses regional and national data. A study using data at the household level could offer a more precise estimate of the results, enabling efficient healthcare campaigns aimed at improving the vaccination rates among households who need it the most. Additionally, exploring the different components of the International Wealth Index might provide a more in-depth analysis of the relation between the vaccination rate and household wealth. This study, for example, argued that access to media potentially improves vaccination outcomes. This could be examined further using household-level data on the International Wealth Index.

Thirdly, since the Area Database from the Global Data Lab is based on surveys like the DHS and the UNICEF MICS, data is only available for the years in which the surveys are conducted. To improve the number of data points, linear interpolation was used to calculate the intermediary datapoints for the dependent and independent variables. Although the linear interpolation method is widely used for missing data, it might bias the results into an inaccurate direction or overestimated significance, especially when the gaps between data points is larger (Junninen et al., 2004). However, the gaps between data points in this dataset were 10 at most which is relatively modest compared to the critical value of 24 values discussed by Junninen et al.

Finally, this study is conducted using a sample of 422 regions within 37 sub-Saharan Africa countries. Hence, 85 regions within 11 countries have been left out of the study as data on the dependent variable were not available. As Appendix B shows, the countries that have been left out are primarily the richest and poorest countries on the African continent in terms of GDP per capita with most of the regions located in the poorest countries (World Bank, n.d.). Therefore, the sample used in this study might be too optimistic, as the findings could be different when the missing countries are included. In future studies, it would therefore be interesting to include the other sub-Saharan Africa countries in order to validate the reliability of the results if data permits.

Despite these limitations, this study has various strengths. Firstly, this study used an extensive data set including the most recent DHS surveys available on the Global Data Lab, which are nationally and regionally representative and based on a large sample of individual surveys. Since many wealth indices are constructed using the data available for a specific year or time, they are not comparable across time and place. The International Wealth Index solves this as it uses the same criteria for rating household wealth, independent of the year or country in which the survey is conducted. Hence, this study ensures that the data between countries and regions are compared using the same criteria. Besides, by using multilevel modelling, this study takes the nested nature of the dataset into account. Therefore, the geographical clustering of the determinants of the vaccination rate can be examined.

Future studies should try to disentangle the effects of the various components of the International Wealth Index to find out which components have an influence on the vaccination rate. Besides, it would be interesting to see what the effects are on the individual level. This could improve public health programmes as these could be altered to reach a more specific audience, further improving the vaccination rate throughout the African continent. It would furthermore be interesting to see if the findings hold when data on the 11 lacking sub-Saharan Africa countries are added as these are among the richest and poorest in sub-Saharan Africa.

# 6. Conclusion

This study aimed to identify the effect of household wealth on the vaccination rate in sub-Saharan Africa by examining the relationship between the International Wealth Index and the vaccination rate of children aged 1. Besides, this study aimed to identify the effect of various other determinants on the vaccination rate. Based on qualitative and quantitative analyses, the conclusion can be drawn that household wealth is an important determinant of the vaccination rate. The results indicate that the vaccination rate is positively influenced by household wealth, maternal education, female empowerment, living with grandparents, and health expenditure, while it is negatively influenced by larger household size and higher levels of corruption. Additionally, the results indicate that the interaction between higher maternal education and more female empowerment leads to a higher vaccination rate, whereas this effect is lower for the interaction between more household wealth and higher maternal education. By using the International Wealth Index, this study conducted one of the first comparable asset-based studies on the vaccination rate between sub-Saharan Africa countries across time and place. The results confirm earlier findings that household wealth is indeed a positive determinant of the vaccination rate.

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# 8. Appendix

## Appendix A. Overview of Countries, Regions, and Years Included

Table 5

*Countries, number of regions, and period of analysis (37 countries, 422 regions)*

| Country | Number of regions | Period of Analysis |
|---|---|---|
| Angola | 18 | 2016 |
| Benin | 6 | 2000 - 2018 |
| Burkina Faso | 13 | 2000 - 2010 |
| Burundi | 5 | 2010 - 2017 |
| Cameroon | 10 | 2000 - 2018 |
| Chad | 8 | 2000 - 2015 |
| Comoros | 3 | 2000 – 2012 |
| Congo Brazzaville | 12 | 2005 - 2011 |
| Congo Democratic Republic | 11 | 2007 – 2013 |
| Cote d'Ivoire | 10 | 2000 – 2011 |
| Eritrea | 6 | 2000 – 2002 |
| Eswatini | 4 | 2006 |
| Ethiopia | 11 | 2000 – 2016 |
| Gabon | 10 | 2000 – 2012 |
| Gambia, The | 8 | 2013 |
| Ghana | 10 | 2000 – 2014 |
| Guinea | 8 | 2005 – 2018 |
| Kenya | 8 | 2000 – 2014 |
| Lesotho | 10 | 2004 – 2014 |
| Liberia | 21 | 2007 – 2013 |
| Madagascar | 28 | 2000 – 2009 |
| Malawi | 13 | 2000 – 2016 |
| Mali | 8 | 2000 – 2018 |
| Mauritania | 12 | 2001 |
| Mozambique | 11 | 2000 – 2011 |
| Namibia | 13 | 2000 – 2013 |
| Niger | 7 | 2000 – 2012 |
| Nigeria | 37 | 2000 - 2018 |
| Rwanda | 5 | 2000 – 2015 |
| Senegal | 10 | 2000 – 2018 |
| Sierra Leone | 14 | 2008 – 2018 |
| South Africa | 9 | 2000 – 2016 |
| Tanzania | 25 | 2000 – 2015 |
| Togo | 6 | 2000 – 2014 |
| Uganda | 13 | 2000, 2001, 2006 – 2016 |
| Zambia | 9 | 2000 – 2018 |
| Zimbabwe | 10 | 2000 - 2015 |

## Appendix B. Overview of Countries and Regions Excluded

Table 6

*Countries and number of regions not analysed (11 countries, 85 regions)*

| Country | Number of regions |
|---|---|
| Botswana | 10 |
| Cabo Verde | 5 |
| Central African Republic | 6 |

Table 6 Continued

| Country | Number of regions |
|---|---|
| Equatorial Guinea | 5 |
| Guinea-Bissau | 9 |
| Mauritius | 3 |
| Sao Tome and Principe | 4 |
| Seychelles | Unk. |
| Somalia | 18 |
| South Sudan | 10 |
| Sudan | 15 |

## Appendix C. Variance Inflation Factor

Table 7
*Variance Inflation Factor*

| | VIF | 1/VIF |
|---|---|---|
| Household wealth | 5.11 | 0.20 |
| Health expenditure | 1.58 | 0.66 |
| Urbanisation | 2.83 | 0.35 |
| Maternal education | 3.93 | 0.25 |
| Household size | 3.34 | 0.30 |
| Power dynamics | 2.45 | 0.41 |
| Living with grandparents | 2.56 | 0.39 |
| Corruption | 1.41 | 0.71 |
| Mean VIF | 2.22 | . |

## Appendix D. Robustness Test Measles

Table 8
*Descriptive Statistics using Measles*

| VARIABLES | (1)<br>N | (2)<br>mean | (3)<br>sd | (4)<br>min | (5)<br>max |
|---|---|---|---|---|---|
| Vaccination rate | 4,926 | 69.79 | 20.32 | 0 | 100 |
| Household wealth | 4,926 | 29.80 | 15.48 | 2.84 | 86.30 |
| Health expenditure | 4,926 | 249.10 | 792.20 | 11.42 | 8,431 |
| Urbanisation | 4,926 | 31.73 | 26.03 | 0 | 100 |
| Maternal education | 4,926 | 3.97 | 2.57 | 0.08 | 11 |
| Household size | 4,926 | 6.96 | 1.84 | 4.09 | 17.70 |
| Power dynamics | 4,926 | 7.88 | 2.26 | 2.40 | 14.30 |
| Living with grandparents | 4,926 | 9.35 | 7.40 | 0.61 | 57.22 |
| Corruption | 4,926 | 2.86 | 0.82 | 1 | 5.70 |

Table 9

*Multilevel Random Coefficient Regression Output using Measles*

| | (1)<br>Random Coefficient | (2)<br>Model (1) incl. regional control variables | (3)<br>Model (2) incl. national control variables | (4)<br>Model (3) incl. interaction terms |
|---|---|---|---|---|
| Household wealth | 0.56*** | 0.26** | 0.17* | 0.20* |
| | (0.077) | (0.083) | (0.086) | (0.079) |
| Urbanisation | | -0.06*** | -0.03** | -0.01 |
| | | (0.011) | (0.012) | (0.013) |
| Maternal education | | 3.31*** | 3.40*** | 3.32*** |
| | | (0.198) | (0.198) | (0.196) |
| Household size | | -2.87*** | -2.86*** | -2.77*** |
| | | (0.202) | (0.201) | (0.196) |
| Power dynamics | | -1.40*** | -1.31*** | -0.50** |
| | | (0.179) | (0.180) | (0.184) |
| Living with grandparents | | 0.46*** | 0.49*** | 0.47*** |
| | | (0.042) | (0.042) | (0.041) |
| Health expenditure | | | 4.97*** | 4.84*** |
| | | | (0.606) | (0.591) |
| Corruption | | | -0.95* | -0.71 |
| | | | (0.408) | (0.398) |
| Household wealth x maternal education | | | | -0.07*** |
| | | | | (0.009) |
| Maternal education x power dynamics | | | | 0.60*** |
| | | | | (0.055) |
| Household wealth x urbanisation | | | | 0.0009 |
| | | | | (0.0006) |
| Constant | 56.77*** | 82.59*** | 61.37*** | 55.21*** |
| | (3.706) | (3.871) | (4.820) | (4.960) |
| Observations | 4926 | 4926 | 4926 | 4926 |
| Log lik | -18939.7 | -18444.0 | -18410.1 | -18277.3 |
| Intraclass cor | 0.802 | 0.800 | 0.818 | 0.845 |

Standard errors in parentheses

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

Note. Model (4) uses centred variables for household wealth, maternal education, power dynamics, and urbanisation in the interaction terms.

## Appendix E. Robustness Test excluding Nigeria

Table 10

*Descriptive Statistics excluding Nigeria*

| VARIABLES | (1) N | (2) mean | (3) sd | (4) min | (5) max |
|---|---|---|---|---|---|
| Vaccination rate | 4,223 | 68.60 | 22.12 | 1.10 | 100 |
| Household wealth | 4,223 | 28.61 | 15.78 | 2.84 | 86.30 |
| Health expenditure | 4,223 | 263.00 | 854.60 | 11.42 | 8,431 |
| Urbanisation | 4,223 | 30.96 | 26.63 | 0 | 100 |
| Maternal education | 4,223 | 3.80 | 2.51 | 0.08 | 11 |
| Household size | 4,223 | 7.04 | 1.90 | 4.09 | 17.70 |
| Power dynamics | 4,223 | 7.59 | 2.25 | 2.40 | 14.30 |
| Living with grandparents | 4,223 | 9.84 | 7.77 | 0.61 | 57.22 |
| Corruption | 4,223 | 2.97 | 0.80 | 1.60 | 5.70 |

Table 11

*Multilevel Random Coefficient Regression Output excluding Nigeria*

| | (1) Random Coefficient | (2) Model (1) incl. regional control variables | (3) Model (2) incl. national control variables | (4) Model (3) incl. interaction terms |
|---|---|---|---|---|
| Household wealth | 0.59*** | 0.68*** | 0.51*** | 0.53*** |
| | (0.080) | (0.094) | (0.096) | (0.090) |
| Urbanisation | | -0.17*** | -0.12*** | -0.09*** |
| | | (0.016) | (0.017) | (0.019) |
| Maternal education | | 1.58*** | 1.89*** | 1.91*** |
| | | (0.293) | (0.292) | (0.288) |
| Household size | | -1.60*** | -1.53*** | -1.74*** |
| | | (0.277) | (0.274) | (0.272) |
| Power dynamics | | -2.07*** | -1.81*** | -1.13*** |
| | | (0.240) | (0.239) | (0.257) |
| Living with grandparents | | 0.33*** | 0.34*** | 0.36*** |
| | | (0.057) | (0.057) | (0.057) |
| Health expenditure | | | 4.25*** | 3.95*** |
| | | | (0.786) | (0.777) |
| Corruption | | | 2.98*** | 2.89*** |
| | | | (0.542) | (0.535) |
| Household wealth x maternal education | | | | -0.12*** |
| | | | | (0.014) |
| Maternal education x power dynamics | | | | 0.26** |
| | | | | (0.082) |
| Household wealth x urbanisation | | | | 0.003*** |
| | | | | (0.0009) |

Table 11 Continued

| | (1) Random Coefficient | (2) Model (1) incl. regional control variables | (3) Model (2) incl. national control variables | (4) Model (3) incl. interaction terms |
|---|---|---|---|---|
| Constant | 53.19$^{***}$ | 74.76$^{***}$ | 45.14$^{***}$ | 42.78$^{***}$ |
| | (3.832) | (4.595) | (5.966) | (6.048) |
| Observations | 4223 | 4223 | 4223 | 4223 |
| Log lik | -16748.6 | -16596.2 | -16555.3 | -16493.2 |
| Intraclass cor | 0.768 | 0.774 | 0.787 | 0.806 |

Standard errors in parentheses
$^{*}$ $p < 0.05$, $^{**}$ $p < 0.01$, $^{***}$ $p < 0.001$
Note. Model (4) uses centred variables for household wealth, maternal education, power dynamics, and urbanisation in the interaction terms.