Association between malaria prophylaxis stock-outs, and birth and maternal outcomes in Zimbabwe

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Abstract

Approximately three hundred thousand mothers and sixty-seven percent of children die from preventable and treatable diseases globally despite rapid developments in medicines over the years. Pregnant women, neonates and children under five are particularly vulnerable to malaria and bear the burden of malaria infections. Understanding the preventive efforts against malaria is therefore crucial. This paper investigates the association between malaria prophylaxis stock-outs and birth and maternal health outcomes in Zimbabwe. Combining the administrative data on stock-outs of malaria prophylaxis and 2015 nationally representative Demographic Health Survey data, we examine malaria prophylaxis stock-outs and birth and maternal health outcomes. Malaria prophylaxis stock-outs are prevalent and increasing over time in Zimbabwe. We also note regional disparities in malaria prophylaxis stock-outs, where stock-outs are more prevalent in some districts than others. Using pooled OLS, malaria prophylaxis stock-outs are significantly associated with birth weight. Drug stock-outs are, therefore, associated with compromised birth health outcomes while significantly associated with only haemoglobin levels for urban women. Malaria prophylaxis stock-outs significantly push neonates with average birth weights towards the lower end of normal birth weight, hence increasing developmental disabilities in these neonates. In addition, drug stock-outs are insignificantly associated with child underweight, stunting and wasting. We recommend that policymakers invest in pharmaceutical information systems and stock ordering systems to prioritise the prevention of malaria and improve maternal and birth outcomes as proposed by the Sustainable Development Goals. This improves drug availability in areas where they are most needed.

JEL Classification Codes: I10, I18, H57

Keywords: malaria prophylaxis, stock-outs, birth weight; maternal anaemia, Zimbabwe

1. Introduction

Pregnant women and neonates are more vulnerable and overwhelmed by the adverse effects of malaria despite the rapid advances in medicines in recent decades. Mothers and their neonates die from preventable and treatable diseases in developing countries (Bhattacharya et al., 2020). This is evidence of malfunctioning health systems associated with low access and use of life-saving services in times of need (Das et al., 2008; Friedman et *al*., 2022; Hill et al., 2013; Rao et *al.*, 2013). The malfunctioning health system exists at a time when drugs are crucial in improving the health outcomes of vulnerable groups. Women lose immunity against malaria during pregnancy, due to changes in immunity and the existence of a placenta, which is easily infected by the parasites (Centers for Disease Control and Prevention, 2018). Understanding the relationship between malaria prophylaxis stock-outs and birth and maternal health outcomes helps in preventing malaria infections during pregnancy to promote the achievement of the Sustainable Development Goals (SDGs).[1]

About eleven million pregnant women were exposed to malaria in 2018 (WHO, 2020) and around four in every ten women were anaemic (WHO, 2019a). According to WHO (2023), approximately three hundred thousand women died in 2020 during pregnancy and birth, with around ninety-five percent of these women from developing countries. Furthermore, 16% (822 000) of the children had low birth weight and 67% (277 000) of under-five children died in 2018 due to malaria in developing countries (WHO, 2020). Similarly, Zimbabwe faces a high burden of malaria which falls heavily on pregnant women and their neonates. This high burden contributes to high maternal mortality of 651 deaths per 100 000 live births, 10% prevalence in low birth weight and 27% maternal anaemia in 2015 (ZIMSTAT and ICF International, 2016). The poor and rural populations are more likely to be affected compared to the affluent and urban populations (Lukwa et al., 2022). As argued by Ticconi et al. (2003), low birth weight is a major contributor to poor child development and infant mortality, which manifests the relevance of early malaria prevention during pregnancy. On that note, the low birth weight would be reduced if pregnant

[1] These targets include SDG 3.1, 3.2 and 3.8. SDG 3.1 "By 2030, reduce the global maternal mortality ratio to less than 70 per 100 000 live births." Target 3.2 "By 2030, end preventable deaths of newborns and children under 5 years of age, with all countries aiming to reduce neonatal mortality to at least as low as 12 per 1 000 live births and under-5 mortality to at least as low as 25 per 1 000 live births." Target 3.8 "Achieve universal health coverage, including financial risk protection, access to quality essential health-care services and access to safe, effective, quality and affordable essential medicines and vaccines for all."

women receive adequate doses of malaria prophylaxis in developing countries (WHO, 2020).

To reduce malaria infections, pregnant women are expected to receive intermittent preventive treatment in pregnancy (IPTp) during antenatal care visits. Sulfadoxine-Pyrimethamine (SP) is administered as the IPTp regardless of malaria status. At least three doses of SP are recommended for pregnant women from the second trimester until delivery; with at least four antenatal care visits to increase the chances of receiving more SP doses. According to WHO (2020), IPTp effectively reduces malaria infections hence reducing negative health outcomes like low birth weight and maternal anaemia. In that regard, not receiving the IPTp increases the chances of malaria infection which affect the red blood cells of pregnant women and further compromises birth and maternal health outcomes. Despite the effectiveness and affordability of malaria prophylaxis, they cannot work if they are not taken, and they cannot be taken if they are not available. Despite high antenatal care visits, pregnant women tend to receive less than the recommended doses of SP (Bausell & Katherine, 2014; Ndyomugyenyi & Katamanywa, 2010). Thus, there exists an impasse in the administration of IPTp and antenatal care visits, and drug stock-outs are one of the reasons for less IPTp uptake regardless of high antenatal care visits (Chikwasha *et al.*, 2014; Ndyomugyenyi and Katamanywa, 2010).

Drug stock-outs can be defined as the total absence of specific drugs at the point of care for at least a day (Hwang *et al.*, 2019; Medecins Sans Frontieres, 2015). These drug stock-outs prevail at a time when malaria burden is rampant and the need to use the drugs is high in developing countries. Frequent drug stock-outs exposed around 219 million vulnerable populations to mortality worldwide (Pitts, 2013). According to prior literature, drug stock-outs are a result of poor supply management, poor coordination between warehouse and facility management, theft, expiry, increase in unexpected demand, lack of funding and unskilled health workers managing the facilities (Koomen *et al*., 2019; Munedzimwe, 2017; Wagenaar *et al.*, 2014). Furthermore, drug stock-outs lead to reduced retention of patients to care, treatment resistance, worsened health status and death in some cases (Bhattacharya *et al.*, 2020; Gils *et al.*, 2018; Koomen *et al.*, 2019; Qiu and Dungca, 2015). Drug stock-outs pose a significant public health challenge in developing countries, where an average of 50% of essential medicines are unavailable, as reported by Cameron *et al*. (2011).[2]

[2] Availability of drugs was measured using WHO/Health Action International standard methodology. The information used to measure availability of drugs was collected from health

Similarly, drug stock-outs are also a public health challenge in Zimbabwe. Literature on drug stockouts in Zimbabwe is scant and it is challenging to determine the extent of this problem. Zimbabwe faces frequent drug stock-outs, with the availability of drugs varying between 55 to 72% in 2019 (Parliament of Zimbabwe, 2019). An assessment using the drug stockout data from the Ministry of Health and Child Care (MoHCC) showed that two in every five facilities surveyed experienced SP stockouts on average from 2011 to 2015 in Zimbabwe. According to ZSARA (2015), around three-fifths of the Zimbabwean facilities did not have SP drugs in 2014. Regardless of enough storage at the central and provincial levels, storage is a problem at the periphery health facility which tends to damage the health products, expiry before use and theft in Zimbabwe hence increasing the likelihood of stock-outs (The Global Fund, 2020). Additionally, the drugs at the health facilities are not always sufficient to cover a maximum period of six months, indicating inadequate drugs in times of disease outbreaks and high demand (MoHCC, 2011).

Prior studies pointed to drug stock-outs as one of the factors limiting pregnant women from receiving adequate doses of SP (Bausell & Katherine, 2014; Bhattacharya et al., 2020; Chikwasha et al., 2014; Rao et al., 2013). Despite existing literature on factors influencing IPTp uptake, empirical analysis of health implications of malaria prophylaxis stock-outs on pregnant women and their neonates remains undocumented. Moreover, studies have been conducted regarding the health effects of drug stock-outs, mainly antiretroviral and anti-tuberculosis drugs (Atif et al., 2021; Koomen et al., 2019; Mori and Owenya, 2014; Pasquet et al., 2010; Poku et al., 2017; Seunanden and Day, 2014), but less is known for malaria prophylaxis stock-outs. Although, high levels of stock-outs for malaria prophylaxis in developing countries are well-documented, to the best of the author's knowledge the health association with these stock-outs remains understudied.

Information on malaria prophylaxis stockouts and maternal and birth outcomes is important to enable the achievement of Vision 2030, mainly focusing on reducing neonatal, infant and maternal mortality. Given that Zimbabwe is among countries with high maternal and child mortality, the empirical evidence makes a significant contribution to improving healthcare service provision for vulnerable groups. Against this backdrop, the paper adds

facilities (public facilities, private facilities, dispensaries, pharmacies and any facilities that serve drugs) in 43 countries for around 15 drugs. Trained data collectors conducted the data collection and then the data was recorded in the Microsoft excel. The data also include information on medicine prices. Availability was calculated as the number of facilities with stock on the day of data collection (Cameron *et al*., 2011).

to the existing body of academic literature on drug stock-outs and health outcomes. The results may assist policymakers in making informed decisions regarding efforts to reduce the negative health consequences of malaria on pregnant women and their neonates.

The main objective of the paper is to examine the association between malaria prophylaxis stock-outs, birth weight and maternal anaemia in Zimbabwe. Following the research objective, the paper hypothesises that women who do not receive malaria prophylaxis during pregnancy are at risk of malaria infections, therefore suffer from low birth weight and maternal anaemia. Thus, malaria prophylaxis stock-outs are associated with low birth weight and maternal anaemia. The research aims to answer the question, do malaria prophylaxis stock-outs influence birth weight and maternal anaemia in Zimbabwe?

2. Literature review

Theoretical literature review

The Grossman model explains the individual's demand for healthcare services to improve their health outcomes (Grossman, 1972). The model notes that individuals are both producers and consumers of healthcare services. Individuals tend to invest in health through direct inputs which are time and market inputs (including diet, recreation and medical care) (Nocera & Zweifel, 1998). The health level of an individual depends on the amount of resources allocated towards health production using time and market inputs (Nocera & Zweifel, 1998). Medical care includes the drugs that are used to prevent and treat diseases, therefore, enhancing health outcomes. Given the important role of drugs in the health sector, it is essential to ensure their availability at the point of need. Women and children have to access essential medical care in the form of drugs to prevent and treat diseases that they mostly suffer from, malaria included. The malaria drugs reduce malaria infections in pregnant women, therefore reducing the negative health outcomes that emanate from malaria infections. Therefore, the unavailability of essential medical care at the point of care is more likely to have negative effects on the health of vulnerable groups. According to existing literature, malaria infections increase the chances of maternal anaemia which therefore compromises the birth outcomes of their neonates (Bakken & Iversen, 2021). Malaria in pregnancy tends to infiltrate the immune cells and compromise the functioning of these cells, thus, thickening the placenta and making it difficult for necessary nutrients to reach the fetus (Bakken & Iversen, 2021). In that regard, malaria

prophylaxis enhances birth and maternal health outcomes in malaria-prone areas, by improving birthweight and haemoglobin levels. According to Mwabu (2008), the healthcare demand analysis is used to improve access to healthcare services by concentrating on the prices of the services, service availability, household income and health insurance. Therefore, the understanding of the quality and availability of healthcare services helps policymakers with information that improves the efficiency and equity of the services towards vulnerable groups (Mwabu, 2008). In the same vein, understanding the effects of malaria prophylaxis stock-outs is crucial in making sure that pregnant women receive the necessary services during antenatal care visits, particularly in malaria endemic areas.

Conceptual framework

Figure 1 shows the conceptualised framework of how demand and supply factors affect birth outcomes. This framework has been adapted from Chera et al. (2015). Supply-side factors include the policy environment and human and financial resources, which influence the training and performance of health workers, supply chain management, behaviour change communication and research (Aberese-Ako et al., 2020; Bajaria et al., 2019; Bausell & Katherine, 2014; Chera et al., 2015; Koblinsky et al., 1995). On the other hand, demand-side factors comprise individual and household factors; socioeconomic status (SES), HIV status, parity, birth interval and distance to the nearest health facility (Bausell & Katherine, 2014; Boateng et al., 2018; Chera et al., 2015; Khan et al., 2020; Rahman et al., 2021; Sunguya et al., 2021; Tamirat et al., 2021). SES in the form of education, wealth and education influences need factors and health awareness and is expected to be correlated to distance to the facility. In turn, these factors affect ANC visits during which SP doses are administered while wealth, education and employment affect health outcomes directly. WHO advocated for women to have enhanced ANC visits to ensure uptake of at least three doses hence healthy pregnancy and improved health outcomes (Khan et al., 2020; Mahumud et al., 2017).

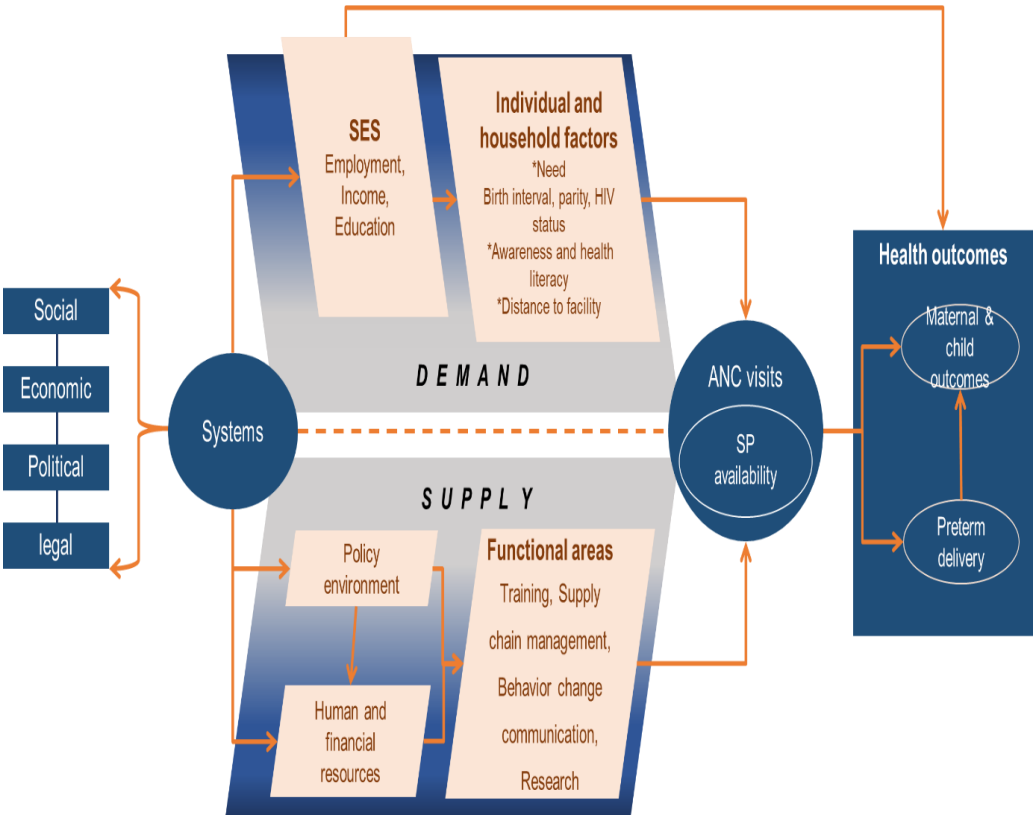

Figure 1: Conceptual framework for birth outcomes (Adapted from Chera, et al. (2015)

Education enhances women's health knowledge, thereby increasing antenatal care uptake and improving birth outcomes, such as reducing the likelihood of low birth weight (Koblinsky et al., 1995; Ndugga et al., 2020; Sunguya et a*l.*, 2021; Tamirat et al., 2021).

Healthcare service utilisation and outcome are also influenced by employment status and household wealth. Affluent and employed women tend to use healthcare services more than poor and unemployed women, given their enhanced capacity to afford the services and the services being in their proximity (Ndugga et al., 2020), which improves their health outcomes (Hill et al., 2013). Being employed provides women with the financial capacity to use better-quality services and make important health decisions without first seeking their husband's permission (Ndugga et al., 2020). Employed women from wealthy households are directly associated with improved health outcomes through adequate maternal nutrition and knowledge of possible health effects of late utilisation of appropriate health services (Chikwasha et al., 2014; Ndugga et al., 2020; Tamirat et al., 2021).

Distance to the health facility also influences access to healthcare services. Women residing far from health facilities are less likely to seek antenatal care and have limited access to essential healthcare services, resulting in compromised health outcomes (Chera et al., 2015; Ndugga et al., 2020). Given the underdeveloped infrastructure and transport systems in rural areas, weak access to services as a result of long travel distances remains a challenge in most developing countries. Women residing in rural areas, therefore, tend to travel a long distance to the closest facility compared to their urban counterparts and have weak access to services.

Other factors influencing the utilisation of healthcare services in times of need are birth interval and parity. Parity and birth interval are influenced by SES, women in higher socioeconomic groups tend to have fewer children and longer birth intervals than those from lower socioeconomic groups. Furthermore, women with more children are likely to be constrained in accessing healthcare services due to increased financial demands and responsibilities (Ndugga et al., 2020). As supported by Sunguya et al. (2021), women with prior birth experiences tend to have a high prevalence of anaemia and birth weight compared to women with first pregnancies. However, multiparous women have increased knowledge of ANC visits benefits and maternal nutrition based on their previous experiences (Chikwasha et al., 2014; Hill et al., 2013). The previous experiences, therefore improve antenatal care and birth weight. On the other hand, a shorter birth interval is associated with low uptake of healthcare services due to late recognition of pregnancy as well as more responsibility from the other children (Tamirat et al., 2021; WHO, 2007).

Besides demand-side factors, supply-side factors also influence the utilisation of maternal healthcare services. Training, supply chain management, behaviour communication change and research are important in enhancing healthcare services availability at the point of care. Specifically, poor supply chain management increases the likelihood of SP stock-outs at a facility which compromises health outcomes. Hence, it is important to ensure SP availability at the facility through improved supply chain management.

The framework shows that health outcomes such as low birth weight and preterm delivery are affected by demand and supply factors, both directly or indirectly. Therefore, appropriate policies to improve health outcomes should address these demand and supply factors, for instance, work status, education and supply chain management.

Empirical literature review

The empirical literature review explores the existing literature on the disruption of healthcare services and related health outcomes. Several studies investigated the health implications of drug stock-outs and the unavailability of health workers in developing countries (Atif et al., 2021; Friedman et al., 2022; Gils et al., 2018; Seunanden & Day, 2014). However, there is a dearth of literature on the association between malaria prophylaxis stock-outs and maternal and neonatal health outcomes, despite malaria being one of the major causes of mortality and morbidity in developing countries.

Several studies have been conducted on the health implications of drug stock-outs. Koomen et al., (2019) and Seunanden and Day (2014) examined the health implications of anti-tuberculosis stock-outs in South Africa whilst Mori and Owenya (2014), Poku et al. (2017) and Pasquet et al. (2010) (using cox regression model) focused on antiretroviral drug stock-outs in Tanzania, Ghana and Cote d'Ivoire, respectively. In addition, using descriptive analysis, Atif et al. (2021), Mclaughlin et al. (2013) and Qiu and Dungca (2015) investigated the effects of drug stock-outs on health outcomes in Pakistan, the US and Kenya, respectively. Brennan et al. (2017) used linear regression and Gils et al. (2018) also used descriptive analysis to analyse HIV treatment stock-outs and health outcomes in South Africa and the Democratic Republic of Congo, respectively. These studies found mixed results on drug stock-outs and health outcomes. In that regard, Atif et al. (2021), Koomen et al. (2019), Mclaughlin et al. (2013), Pasquet et al. (2010), Qiu and Dungca (2015), Seunanden and Day (2014), Mori and Owenya (2014) and Poku et al. (2017) found that drug stock-outs at the health facility worsen individuals' health outcomes, while Brennan et al. (2017) and Gils et al. (2018) found that drug stock-outs have no effects on health outcomes. Brennan *et al.* (2017) and Gils *et al.* (2018) noted that patients are usually provided with alternative drugs or referred to a nearby facility with stock during stock-outs at the focal facility. Thus, these solutions counteract the negative health effects associated with drug stock-outs.

Although these studies examined the health implications of drug stock-outs, Koomen et al. (2019) and Seunanden and Day (2014) used the proportion of facilities stocked out to depict drug stock-outs in their analysis rather than the number of days with stock-outs. Atif et al. (2021), Brennan et al. (2017), Gils et al. (2018), Pasquet et al. (2010), and Poku et al. (2017) used drug stock-outs collected from a health facility on a specific day to illustrate stock-out in the analysis. This is not a true representation of stock-out at the facility and overstates stock-outs, given that a day without drugs at the facility is less harmful than a week or month of stock-outs. The current paper used the

proportion of days stocked out within two quarters at each facility when women were supposed to receive the drug as a measure of drug stock-outs.

3. Measures and methods

Data sources

We combined the government administrative drug stockout data and the nationally representative 2015 demographic health survey (DHS) to explore the association between malaria prophylaxis stock-out and health outcomes in Zimbabwe.

Malaria prophylaxis stockout data is collected from the MoHCC. The Department of Pharmaceutical Services is responsible for data collection. All the facilities submit their stock management information to the MoHCC, which then further compiles the information. The data collect information from all the facilities that offer IPTp drugs from all the districts in the country. Furthermore, the stock-out data are collected quarterly per facility from 2011 to 2015. The data show the information on the facility, district, province, date when the information was recorded, stock at hand and the number of days the drug is stocked out at the facility. The drug stock-out information helps to assess the prevalence and effects of malaria prophylaxis stock-out in Zimbabwe, as it is used as a measure of healthcare quality for pregnant women and their neonates.

DHS data are collected in many developing countries after every five years and the survey was also conducted in Zimbabwe from 1988 to date. The survey is conducted by the Zimbabwe National Statistical Agency in partnership with the MoHCC and other non-government organisations. DHS collects information on sociodemographic variables, fertility, child, and maternal mortality health. The data is a true representation of the population as it is collected from all the country's ten provinces using the national census data. The data are collected using a two-stage stratified cluster sampling method. Enumeration Areas are selected first using proportional probability to size and after that households were allocated to their respective enumeration areas. The paper used the women's questionnaire aged 15-49 which contains information on birth and maternal health outcomes.

Specifically, the paper used the 2015 DHS to explore the effects of malaria prophylaxis stock-out on birth and maternal health outcomes. A total of 400 enumeration areas were selected from the population with an average of 24 households in every enumeration area. The 2015 survey was conducted from July to December 2015 comprising a sample of 11 196 households derived from the 2012 population census data. 10,351 women were eligible for the

interview with a 92% success rate. However, the information on women who gave birth and children born in 2011, 2012, 2013, 2014 and 2015 were used in the analysis and 2010 health outcomes information was dropped since the drug stock-out data does not contain respective information. Some of the variables had missing information hence reducing the number of observations in the analysis. Thus, the analysis was possible for over four thousand observations after missing observations and births in 2010 and below are excluded.

The DHS data was collected in 2015, however, this is the most recent data which has maternal and neonatal health outcomes data suitable for this paper. The dataset was, therefore, relevant for the analysis considering that the health problems that prevailed in 2015 are still prevailing and currently affecting individual health. Maternal mortality, low birth weight and maternal anaemia have reduced over time, however, they are still above what is stipulated in the SDGs. This remains a problem as maternal mortality in Zimbabwe remains the highest in the Southern Africa Development Community (ZIMSTAT and ICF International, 2016; ZSARA, 2015). The level of stock-out of malaria prophylaxis is high in Zimbabwe, thus, drug stock-out are still a challenge and affect the health outcomes of the vulnerable population. Although recent data for drug stock-out exist, they cannot be matched to any health outcomes data for the respective period.

Linking facility and household data have been prominent in measuring the quality of health services women receive during pregnancy. However, linking facility and household data presents challenges, as the location of households is anonymised and pregnant women sometimes do not use the nearest facilities (Mallick et al., 2017). The drug stock-out and DHS data were linked using the Global Position System coordinates. The DHS cluster coordinates were linked to the facility coordinates to merge the health outcomes information and malaria prophylaxis stock-out information. Although a cluster is serviced by at least two facilities, only the closest facility to the cluster coordinates is considered in the analysis. DHS cluster coordinates and the facility coordinates were merged assuming that people in the same cluster are more likely to use the same facility. The DHS cluster coordinates were displaced from their original position as a way to protect the household's information. The coordinates are displaced 2 km in urban areas and 5-10 km in rural areas. The displacement of coordinates was done carefully, to ensure that clusters did not overlap with other administrative areas (see Mayala et al., 2018). The comprehensive information on data extraction is found in the DHS geospatial covariates dataset manual (Mayala et al., 2018). Thus, to correct the impact of displacement of coordinates, we used a 10 km "buffer zone".

Facilities within a 10 km radius were used. The facility was omitted if its name was absent from the stock-out database, and the next closest facility was selected.

Malaria in Zimbabwe

Malaria is a global health challenge and Zimbabwe is burdened with malaria with over half of the population at risk of malaria infections (MoHCC, 2020; USAID, 2018). Malaria transmission in Zimbabwe is seasonal and affects regions differently, malaria transmission is normally at its peak between October and May. Areas in the northern, northeast, northwest, eastern and southeast are considered malaria-endemic regions in the country (MoHCC, 2020). These regions are characterised by high and perennial malaria transmission. Despite the reduction in malaria transmission in Zimbabwe, malaria remains a major cause of infant and maternal mortality among pregnant women and children (MoHCC, 2020). Several malaria in pregnancy prevention methods are used in Zimbabwe, which are SP, indoor residual spraying and insecticide-treated nets. These are donor-funded and provided for free in public facilities in Zimbabwe. However, we focused on SP drugs given their effectiveness and efficiency in reducing malaria during pregnancy. These SP doses are offered during antenatal care visits and are mostly found in public hospitals and private facilities have limited implementation of IPTp as part of ANC services (Chikwasha et al., 2014; US President's Malaria Initiative, 2018). Pregnant women are offered SP doses by the health authorities upon attending antenatal care visits.

According to Zimbabwe's MoHCC (2020), only high malaria-endemic districts are recommended to administer SP. Other districts in the country are not recommended to administer SP by the MoHCC, due to low transmission rates. However, the authorities in the low transmission areas still administer SP doses, citing the need to improve the health outcomes of their people (US President's Malaria Initiative, 2017). The other reason authorities administer SP doses in low transmission areas is to cater for pregnant women who reside in high malaria-endemic areas, but whose closest facility is in low malaria-endemic areas. This takes into consideration the fact that accessing health facilities does not dependent on district or province, but on convenience in terms of distance and cost.

Malaria infections still exist in low malaria transmission areas and negatively affect pregnant women and their neonates. Thus, SP uptake will help to reduce malaria infections. Pregnant women are encouraged to receive IPTp, which is provided via direct observation treatment in Zimbabwe (US President's Malaria Initiative, 2018). Health workers provide SP doses to

pregnant women upon attending their routine antenatal care. Furthermore, village health workers are employed by the MoHCC to encourage pregnant women to attend antenatal care early and embrace IPTp by outlining the benefits of taking SP doses during pregnancy. Therefore, pregnant women who have had more antenatal care visits are expected to receive more doses of SP.

Definition of variables

The independent variables were selected from the conceptual framework and prior literature. These independent variables are birth interval, parity, preterm delivery, stock-out index, wealth index, work status, education, geographical location, BMI, currently pregnant and HIV status.

Work status was a dummy variable denoted by working (for women with a paying job or a business) and not working women. Working women were expected to have better health outcomes than non-working while the geographical location was a binary variable denoted by one if location is rural and zero if location is urban.

The wealth index was another variable measured in ZDHS using principal component analysis from the household's assets. This variable measures socioeconomic status and was standardised by subtracting the mean wealth index from the household's wealth index, and then dividing by standard deviation as suggested by prior literature (Rustein & Johnson, 2004). Therefore, women from wealthy families tend to have enhanced health outcomes compared to those from less wealthy households.

Another variable was education which depicted the number of years in which the highest qualification was acquired and educated women were more likely to have improved health outcomes than their uneducated counterparts. Preterm delivery also affects birth and maternal outcomes. Preterm delivery was defined as birth before the 37th week of pregnancy, children born before 37 weeks are preterm represented by one in the analysis and zero if a child is born after 37 weeks of pregnancy. Preterm neonates tend to have lighter birth weights than the non-preterm neonates.

Parity was another variable representing the number of children that the woman has ever given birth to, either stillborn or born alive. The women can either be primiparous or multiparous. Primiparous represents women with only one birth whilst multiparous represents women with at least two births. Prior studies noted that multiparous women were more likely to give birth to lighter neonates than primiparous whilst other studies noted that primiparous tend to give birth to lighter neonates than multiparous women. On the other hand, birth interval shows the spacing between pregnancies by the mother

which affects the health of the children and it was represented by the number of children a woman gave birth to within a year in this paper. Women with short birth intervals were more likely to have compromised birth and maternal outcomes.

Currently pregnant was also a factor affecting maternal outcomes in the analysis. This variable was represented as one if the woman was pregnant during the survey and zero if not pregnant. Pregnant women were more likely to be anaemic than non-pregnant women. Moreover, body mass index (BMI) also affects maternal outcomes. This shows weight divided by a square of the height in meters and women with low BMI are more likely to be anaemic than those with high BMI.

Child nutrition variables were also used as dependent variables to depict the long-run effects of malaria prophylaxis stock-outs. These child nutrition variables include stunting, wasting and underweight. Stunting is defined as the height for age and a child is stunted when the z-score is less than -2 standard deviation. Wasting is the weight for height of a child, children with weight for height less than -2 are considered to be wasted. Underweight children tend to be too thin for their age and have a z-score value of less than -2 standard deviations. Child death is the death of a child before reaching the age of five and is used as a binary variable for one if the child is dead and zero if the child is alive. The analysis was done for different geographical locations, represented by rural and urban. Birth weight and maternal anaemia were the dependent variables and represented neonates' and women's health outcomes, respectively.

Maternal anaemia

While there are many causes of anaemia in pregnant women, including iron deficiency and genetic factors, malaria is considered one of the major causes of maternal anaemia in pregnancy (WHO, 2019a). The WHO (2005) defines anaemia as a condition where the number of red blood cells is below the recommended level. Anaemia is a major contributor to maternal mortality, preterm birth, poor foetal growth, low birth weight and postpartum depression (Ticconi et al., 2003). Furthermore, maternal anaemia is influenced by the number of children, birth interval, lifestyle, HIV, and malaria, to mention a few (Rabiu et al., 2020; Rahman et al., 2021). Pregnant women are more likely to have maternal anaemia as a result of malaria infection at the end of the pregnancy (Huynh et al., 2011; Kalilani-Phiri *et al.*, 2013). Haemoglobin level was used as a measure of maternal anaemia.

Birth weight

Birth weight was used to measure the health outcome association of malaria prophylaxis stock-out and neonates. According to the WHO (2019c), babies with a weight of more than 500g and less than 2 500g are considered to have a low birth weight, which is not desirable for a child's growth. Low birth weight is caused by placental parasitaemia, maternal anaemia, lifestyle and demographic variables such as age, and gravidity (Khan et al., 2020; Mahumud et al., 2017; Tamirat et al., 2021). Children born to mothers with malaria are more likely to have a low birth weight than those born to mothers who are not infected (WHO, 2019a). According to Huynh *et al.* (2011) and Kalilani-Phiri (2013), malaria infections tend to affect birth weight during the first months of pregnancy. Therefore, it is important to note that children with low birth weight face a high risk of stunting, poor cognitive development and infant mortality. Prior studies have also noted that neonates with birth weight at the lower end of normal birth weight (2,500grams-3,000grams) are likely to experience developmental disabilities, for example, mental retardation and intellectual impairment.

Drug stock-outs

Prior studies measured drug stock-out as the drug unavailability on a particular day at a facility (Pasquet et al., 2010; Mclaughlin et al., 2013; Atif et al., 2021; Qiu & Dungca, 2015), however, this does not correctly represent the prevalence of drug stock-outs at a facility. This is mainly because a day without drugs cannot be compared to a month without drugs. The facility might only be stocked out one day whilst drugs are available any other day, thus a day without drugs overstates the stock-out prevalence at facilities. In that regard, a stock-out index which is in line with the period when the woman was pregnant was used to measure drug stock-out in Zimbabwe. It was the core variable in the analysis[3]. The stock-out index was created by calculating stock-out averages for two quarters when the woman was pregnant and expected to receive SP doses. The stock-out index equal to zero represents the zero stock-out and values greater than zero indicate the presence and extent of stock-out. Therefore, stock-out index shows the prevalence of drug stock-outs by using proportion of days SP was stocked out at the facility in six months. The more the number of days with SP stock-outs, the more prevalent the drug stock-out challenge in Zimbabwe and vice versa.

[3] The number of SP doses would have been used as an instrumental variable, however the 2015 DHS dataset does not have information on SP uptake.

Estimation technique

Existing literature on drug stock-out and health outcomes focused on observational data collected in a day, using qualitative method (Atif et al., 2021; Gils et al., 2018; Mclaughlin et al., 2013; Qiu & Dungca, 2015). Koomen *et al. (*2019) used weighted least square regression whilst Brennan *et al.* (2018) used a regression discontinuity model. However, although the latter studies used quantitative methods for analysis, these methods were not appropriate for the data used for analysis. In that regard, since cross-sectional data pooled within one survey was used, the paper estimated the model using pooled OLS.

Equation 1 is estimated to show the association between stock-out and birth weight for neonates and maternal anaemia. The coefficients (α_1) were expected to be negative and were interpreted as a change in health outcomes associated with changes in the independent variables. In that regard, a negative α_1 was interpreted as an increase in the proportion of days stocked out at a facility was associated with a decrease in neonatal birth weight. The dataset was useful in examining a stable relationship between dependent and independent variables over time. The paper used pooled OLS to analyse the relationship between malaria prophylaxis stock-out and birth and maternal health outcomes in Zimbabwe. The pooled OLS models for malaria prophylaxis stock-out and neonatal and maternal health outcomes were specified as follows:

$$y_{ict} = \alpha_1 stockout_{ct} + \alpha_2 X_{ict} + \theta_i + \phi_t + \varepsilon_{ict} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where y_{ict} represented birth outcomes (birth weight, stunting, wasting and underweight) and maternal haemoglobin of the newborn babies for individual *i* in cluster *c* at time *t*. $stockout_{ct}$ is the SP stock-out at cluster *c* (where the cluster is equal to the facility) in period *t*. X_{ict} is the matrix of other control variables in the model, which are preterm delivery, currently pregnant, BMI, parity, geographical location, wealth index, work status, birth interval and HIV status; α_2 is the vector of parameters, whilst ε_{ict} represents the error term. θ_i represents regional fixed effects while ϕ_t represent birth year-fixed effects.

Given the nature of the pooled data, the paper uses the pooled OLS to achieve the research objectives. Pooled OLS yields consistent results of the unknown parameters under certain assumptions and is effective when the error term is not correlated with the explanatory variables. The regional and time fixed effects were incorporated into the analysis to address the heterogeneity problem. Clustered standard errors were used to account for common variations inside survey clusters. Therefore, the paper measured associations and not causal relationships.

4. Estimated results

Table 1 summarises the descriptive statistics for all the variables in the analysis.

Table 1: Descriptive statistics

Variables	Obs	Mean	Std. Dev.	Min	Max
Age (years)	3929	28.105	6.634	15	49
Birth interval (children within a year)	3929	0.344	0.499	0	2
HIV status (HIV negative=0 & HIV positive=1)	3929	0.156	0.363	0	1
Location (urban=0 & rural=1)	3929	0.676	0.468	0	1
Birth weight (grams)	3635	3125.80	581.310	500	5900
Haemoglobin level (grams/deciliter)	3929	12.971	1.683	3.9	18.6
Preterm delivery (preterm=1 & non-preterm=0)	3929	0.029	0.167	0	1
BMI (kg/m^2)	3929	24.176	4.443	14.760	57.74
Currently pregnant (pregnant=1 & not pregnant=0)	3929	0.055	0.228	0	1
Parity (children per woman)	3929	2.896	1.704	1	12
Education (years)	3929	9.008	2.869	0	21
Wealth index (index from PCA)	3929	-0.454	0.990	-1.957	2.400
Work status (not working=1 & working=1)	3929	0.381	0.486	0	1
SP stock-out (proportion of days)	3929	0.065	0.136	0	0.994
Stunting (not stunted=0 & stunted=1)	3929	0.228	0.419	0	1
Wasting (not wasted=0 & wasted=1)	3929	0.034	0.182	0	1
Underweight (not underweight =0 & underweight=1)	3929	0.067	0.250	0	1
Child death (child alive=0 & child dead=1)	3929	0.048	0.213	0	1

Mean age, birth weight and haemoglobin level are 28.11 years, 3125.80g, and 12.97g/dl, respectively. On average, women reported having some secondary education, with the average being nine years of education. A considerable

proportion of women were HIV-positive (15.6%) and women gave birth to one child in a year and had a long birth interval. Concerning SP stock-out, on average, almost ten percent of days had malaria prophylaxis stock-out at the facilities. On average, women had three children, regarded as multiparous. More pregnant women had attended at least four ANC visits, as recommended by the WHO. Relatively few children were wasted, underweight and died before the age of five whilst a considerable proportion of children were stunted. Moreover, only less than two-fifths of the sample was working during the survey while 2.9% of the children were born prematurely. On average, 5.5% of the women were pregnant during the data collection.

Figure 2 illustrates the prevalence of malaria prophylaxis stock-out in different districts from 2011 to 2015.

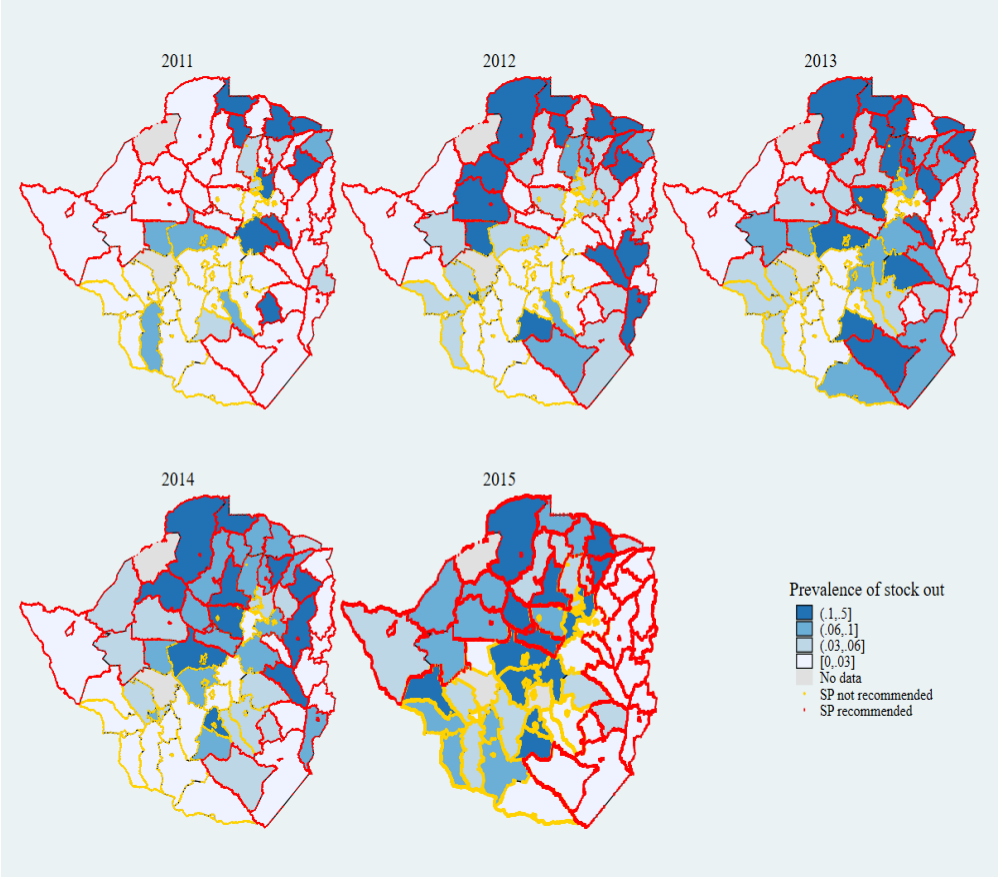

Figure 2: Proportion of days stocked out by district

The figure shows the proportion of days stocked out of the SP during the period. The Zimbabwean map was subdivided into districts, which are bounded by different colours – red (SP recommended) and gold (SP not

recommended). The high prevalence of drug stock-out was noted over time in Zimbabwe. The darker the shade within the district the more the district was suffering from drug stock-out. Malaria prophylaxis stockout was more prevalent in the northern, northeast and northwest parts of the country. The districts burdened by a high prevalence of stock-out are Guruve, Mount Darwin, Rushinga, Mutare, Mberengwa, Nkayi and Gokwe South. Similarly, the northern, northeast and central parts of the country had a high prevalence of stock-outs (refer to Appendix A for district location). These were Hurungwe, Gokwe North, Zvimba, Muzarabani, Gweru, Zvishavane and Mberengwa were prone to SP stock-outs. Moreover, facilities experiencing stock-out in different districts increased over time, from 2011 up to 2015. SP stock-out was more prevalent in malaria-endemic areas which were mandated to administer the SP drug during pregnancy in Zimbabwe. This might be attributed to the high demand for drugs in these areas which are not matched with the supply given their malaria endemicity. On the other hand, eastern and southeast regions tend to have less stock-out prevalence over time.

Malaria prophylaxis stock-out was less prevalent in 2011 compared to 2012-2015 due to missing information during 2011. The capturing of information on drug stock-out started around 2011, which might have affected the amount of data collected in 2011. Some facilities might not have been familiar with the data-capturing method in 2011 and hence did not submit their stock-out reports.

Figure 3 illustrates the relationship between drug stock-out, low birth weight and maternal anaemia in rural and urban areas in Zimbabwe.

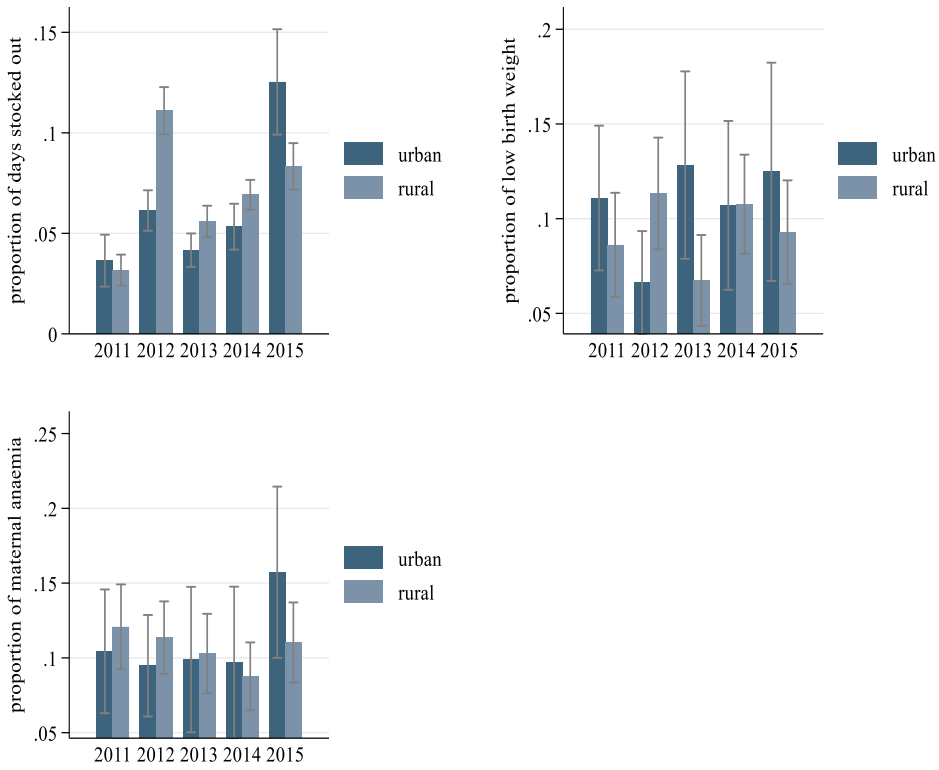

Figure 3: Relationship between stock-out, anaemia and low birth weight in Zimbabwe.

The prevalence was also subdivided into rural and urban locations. SP stock-outs were low in 2011, with less than 5% of the days with stock-out at the facilities. However, the proportion of days stocked out at facilities increased over time, from approximately 3% in 2011 to around 9.5% in 2015. Facilities were more stocked out in 2012 and 2015, as illustrated in Figure 3. Rural facilities faced more SP stock-out in 2011, 2012, and 2013, whilst the urban facilities experienced higher levels of stock-out in 2014 and 2015.

Low birth weight increased over the years, with a decrease in 2013 for urban facilities. At least 6% of neonates had a low birth weight. Neonates in urban areas had lower birth weights than their rural counterparts. Higher proportion of rural neonates compared to urban neonates was recorded in 2012. In 2012, least neonates had low birth weight in urban areas whilst rural neonates had the least low birth weight in 2013. On the other hand, maternal anaemia did

not change significantly from 2011 to 2014 and increased from around 25% in 2014 to around 30% in 2015. Although maternal anaemia did not change significantly, women in rural tend to be more anaemic than women in urban areas.

Table 2 shows the birth weight pooled OLS results for the full sample, urban and rural populations. Univariate and multivariate models were estimated with regional and time fixed effects. SP stock-out, preterm delivery, parity, birth interval, work status, HIV status, wealth index and education. Parity, wealth index and work status are significant and positive in affecting birth weight whilst SP stock-out, birth interval and gender of the child significantly reduce birth weight in Zimbabwe.

Table 2: Pooled OLS results for birth weight

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	Full sample	Full sample	Urban	Urban	Rural	Rural
SP stock-out	-154.231**	-142.146*	-134.351	-53.382	-148.700	-165.884*
	(78.490)	(77.541)	(154.913)	(135.481)	(90.800)	(92.675)
Preterm delivery		-988.643***		-1,256.5***		-761.132***
		(100.602)		(107.470)		(130.013)
Birth interval		-46.107		-10.043		-57.041
		(31.124)		(53.147)		(37.545)
Parity		28.320***		28.280		29.641***
		(7.882)		(17.976)		(8.568)
HIV status		-6.115		63.1120		-37.748
		(31.295)		(53.806)		(37.544)
Wealth index		24.900*		26.059		23.645
		(14.801)		(45.458)		(25.429)

Education		-2.770		-9.418		2.572
		(5.161)		(9.776)		(5.907)
Work status		49.179**		-1.515		76.401***
		(24.357)		(43.004)		(29.365)
Constant	3,145.069***	3,091.001***	3,203.846***	3,265.7***	3,156.381***	3,030.043***
	(45.962)	(80.304)	(78.363)	(152.584)	(52.900)	(94.783)
Regional FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,635	3,432	1,380	1,244	2,255	2,188
R-squared	0.011	0.087	0.018	0.175	0.018	0.065

Robust standard errors in parentheses

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

SP stock-out was significantly associated with birth weight for all the full sample models and rural univariate models. The proportion of days stocked out significantly lowered birth weight for neonates. A proportion increase in the days without SP at facilities was associated with 154.23 grams, 142.15 grams and 165.88 grams reduction in birth weight for the full sample without other variables, the full sample with other variables and the rural sample with other variables, respectively. Prior studies noted that receiving recommended SP doses was associated with the clearance of placental malaria and prevention of malaria infections hence improving birth outcomes (Bakken & Iversen, 2021; Feresu et al., 2015; Mikomangwa et al., 2020). Pregnant women are recommended to receive at least three SP doses during ANC visits to improve their health outcomes, but sometimes they do not receive these due to stock-out (Bajaria et al., 2019; Bausell & Katherine, 2014; WHO, 2019b). Receiving less than three doses increases the probability of malaria infection (Feresu *et al*., 2015). Frequent unavailability of these drugs during antenatal care visits poses a risk, especially for vulnerable groups. The results on drug stock-out and birthweight are in line with the results of Atif et al. (2021), Koomen et al. (2019), Pasquet et al. (2010), and Seunanden and Day (2014).

This was also in line with the results by Friedman et al. (2022) and Goldstein et al. (2013).

In addition, birth weight was negatively associated with preterm delivery. On average, children born preterm were at least 750 grams lighter for all the models than non-preterm children. Children born prematurely before the 37th week of pregnancy have low birth weight compared to children born on or after the 37th week of pregnancy (Feresu *et al.*, 2015). These children are born before their appropriate birth time, at a small gestational age.

Working women significantly had improved birth weight for both the full sample and rural models. Working women gave birth to healthier babies than those who are not working. This result was in line with the results of Mahumud et al. (2017). Working women were empowered and had the financial capacity to access essential healthcare services during antenatal care visits on their own without consulting their husbands (Ndugga et al., 2020). These women have improved knowledge of maternal nutrition and the health implications of late antenatal care visits (Chikwasha et al., 2014; Tamirat et al., 2021).

With regards to parity, neonates of multiparous women have healthier birth weights than the birth weights of children born by primiparous women. This result is consistent with that of Tamirat et al. (2021). Multiparous women have more knowledge of the benefits of antenatal care visits based on their previous experiences hence increased access to healthcare services and ANC visits (Chikwasha et al., 2014; Hill et al., 2013). Women with more children have improved health outcomes given enhanced access to healthcare services (Tamirat et al., 2021).

Birth interval, HIV status and education had an insignificant association between birth weight and malaria prophylaxis stock-out in Zimbabwe

Table 3 shows the results for stunting, wasting, underweight and child death in Zimbabwe.

Table 3: Pooled OLS results for stunting, wasted, underweight and child death

Variables	Stunting			Wasting			Underweight			Child death		
	Full	Urban	Rural	Full	Urban	Rural	Full	Urban	Rural	Full	Urban	Rural
SP stock-out	0.05	-0.11	0.10	-0.019	-0.033	-0.013	-0.010	-0.055	0.001	0.001	0.059	-0.008

	(0.06)	(0.10)	(0.07)	(0.02)	(0.040)	(0.022)	(0.030)	(0.055)	(0.035)	(0.029	(0.073)	(0.031)
Preterm delivery	0.01	-0.07	0.07	0.018	0.054	-0.010	0.039	0.063	0.023	0.28***	0.19***	0.34***
	(0.046)	(0.05)	(0.07)	(0.02)	(0.039)	(0.028)	(0.033)	(0.047)	(0.044)	(0.051)	(0.064)	(0.068)
Birth interval	-0.05**	-0.06	-0.05**	-0.005	-0.005	-0.007	-0.021	-0.001	-0.026*	0.028**	0.017	0.034**
	(0.02)	(0.04)	(0.02)	(0.01)	(0.020)	(0.011)	(0.013)	(0.027)	(0.015)	(0.012)	(0.022)	(0.015)
Parity	0.01	0.02	0.01	0.000	0.007	-0.002	0.001	0.002	-0.002	0.004	0.004	0.004
	(0.01)	(0.01)	(0.01)	(0.002)	(0.005)	(0.002)	(0.003)	(0.007)	(0.003)	(0.002)	(0.004)	(0.003)
HIV status	0.02	0.04	0.01	0.001	-0.007	0.003	0.032**	0.011	0.039**	0.024**	0.022	0.022
	(0.022)	(0.05)	(0.03)	(0.01)	(0.018)	(0.011)	(0.015)	(0.030)	(0.017)	(0.013)	(0.025)	(0.015)
Wealth index	-0.04***	-0.11***	-0.04**	0.01	0.009	0.014**	-0.02***	0.019	-0.024**	-0.001	0.012	-0.002
	(0.01)	(0.03)	(0.02)	(0.004)	(0.011)	(0.006)	(0.006)	(0.016)	(0.011)	(0.005)	(0.017)	(0.008)
Education	-0.01**	-0.01*	-0.01	-0.001	0.003	-0.002	-0.002	-0.002	-0.002	-0.004**	-0.006*	-0.002
	(0.004)	(0.01)	(0.004)	(0.002)	(0.004)	(0.002)	(0.002)	(0.004)	(0.002)	(0.002)	(0.003)	(0.002)
Work status	-0.01	-0.04	0.01	-0.02**	-0.004	-0.02***	0.000	-0.011	0.004	-0.008	-0.007	-0.006
	(0.02)	(0.03)	(0.02)	(0.01)	(0.012)	(0.007)	(0.010)	(0.018)	(0.004)	(0.008)	(0.016)	(0.010)

Constant	0.18***	0.23**	0.18***	0.02	-0.042	0.032	0.035	0.014	0.036	0.07***	0.059	0.067**
	(0.05)	(0.09)	(0.06)	(0.02)	(0.05)	(0.026)	(0.028)	(0.058)	(0.034)	(0.025)	(0.037)	(0.031)
Regional FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,940	1,278	2,662	3,940	1,278	2,662	3,940	1,278	2,662	3,940	1,278	2,662
R-squared	0.04	0.08	0.04	0.03	0.06	0.023	0.022	0.025	0.024	0.055	0.056	0.064

Robust standard errors in parentheses

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

SP stock-out was insignificantly associated with child stunting, wasting, underweight and child death. HIV status and preterm delivery significantly worsen child nutrition in Zimbabwe. HIV status was significantly and positively associated with underweight and child death while preterm delivery was positively related to child death. Birth interval significantly reduced stunting and child death while working was negatively associated with stunting and underweight. Children from educated mothers experienced less child death and stunting compared to children from uneducated mothers. Moreover, children from wealthy families were less likely to be wasted compared to children from poor families. Parity was insignificantly associated with stunting, wasting, underweight and child death in Zimbabwe.

Table 4 shows the malaria prophylaxis stock-out maternal haemoglobin results in Zimbabwe.

Table 4: Pooled OLS results for maternal haemoglobin

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	Full sample	Full sample	Urban	Urban	Rural	Rural
SP stock-out	0.099	0.043	-0.796*	-0.951**	0.373*	0.317

	(0.195)	(0.192)	(0.463)	(0.477)	(0.217)	(0.210)
Currently pregnant		-1.481***		-1.575***		-1.460***
		(0.126)		(0.252)		(0.143)
BMI		0.028***		0.008		0.038***
		(0.007)		(0.011)		(0.009)
Birth interval		-0.173**		-0.019		-0.220**
		(0.074)		(0.126)		(0.089)
Parity		-0.0379**		0.008		-0.049**
		(0.019)		(0.042)		(0.021)
HIV status		-0.883***		-0.979***		-0.851***
		(0.086)		(0.166)		(0.098)
Wealth index		-0.047		0.118		-0.106
		(0.042)		(0.132)		(0.081)
Education		0.007		-0.016		0.010
		(0.012)		(0.121)		(0.014)
Work status		-0.099		-0.086		-0.113
		(0.060)		(0.115)		(0.071)
Constant	13.170***	12.888***	13.165***	13.288***	13.207***	12.666***
	(0.107)	(0.240)	(0.209)	(0.415)	(0.123)	(0.302)
Regional FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,008	3,929	1,314	1,274	2,694	2,655
R-squared	0.024	0.108	0.045	0.134	0.023	0.108

Robust standard errors in parentheses

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

The results show that the SP stock-out was significantly associated with reduced haemoglobin level for the urban samples in Zimbabwe. A proportion increase in days with drug stock-out at the facilities in urban areas reduced

maternal haemoglobin. However, stock-out was not significantly associated with haemoglobin levels for the full sample and the rural sample.

HIV status was significantly associated with reduced haemoglobin levels in Zimbabwe. The present study found that HIV-positive women were more anaemic than HIV-negative women. Being HIV-positive was associated with lower haemoglobin levels by 0.88g/dl, 0.98g/dl and 0.85g/dl for the full sample, urban sample and rural sample, respectively. As noted by Rabiu et al. (2020) and Ticconi et al. (2003), HIV-positive women experience more adverse health effects than those who are HIV-negative and the virus weakens an individual's white blood cells, thereby compromising the immune system, and the body struggles to fight against diseases. A compromised immune system increases the chances of malaria infections, especially in the absence of prophylactic treatment.

Parity, birth interval and BMI were associated with haemoglobin levels for the full sample and rural areas. Pregnant women had reduced maternal haemoglobin levels for mothers by 1.48g/dl in the full sample, 1.58g/dl in urban areas and 1.46g/dl in rural areas. However, work status, wealth index and education were insignificantly associated with haemoglobin levels.

5. Robustness check

A robustness check was done using the semi-log regression model and quantile regression model for birth weight and quantile regression for haemoglobin level, represented by Tables 5, 6 and 7, respectively. Due to the heterogeneity in variables, a semi-log regression model was conducted to check if the results were reliable, unbiased and consistent in the presence of these challenges. Quantile regression was also used for robustness check given the existence of heterogeneity and showed the influence of SP stock-out on birth weight and haemoglobin level over different quantile distributions. The robustness checks, therefore, showed that the results are not statistically different from the results obtained using pooled OLS. This showed that the results were unbiased and consistent, therefore the results are reliable and can be used to proffer policy recommendations in Zimbabwe.

Table 5: Semi-log regression results for birth weight

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	Full sample	Full sample	Urban	Urban	Rural	Rural
SP stock-out	-0.054**	-0.048*	-0.063	-0.024	-0.046	-0.053*

	(0.028)	(0.026)	(0.062)	(0.048)	(0.030)	(0.031)
Preterm delivery		-0.423***		-0.523***		-0.333***
		(0.048)		(0.057)		(0.063)
Birth interval		-0.015		-0.006		-0.021
		(0.011)		(0.018)		(0.014)
Parity		0.009***		0.010		0.010**
		(0.003)		(0.006)		(0.003)
HIV status		-0.003		0.024		-0.015
		(0.011)		(0.017)		(0.013)
Wealth index		-0.008		0.009		0.006
		(0.005)		(0.017)		(0.009)
Education		0.001		-0.004		0.001
		(0.002)		(0.004)		(0.002)
Working status (working)		0.016*		0.000		0.023**
		(0.009)		(0.016)		(0.010)
Constant	8.029***	8.011***	8.052***	8.076***	8.034***	7.978***
	(0.016)	(0.029)	(0.028)	(0.051)	(0.018)	(0.025)
Regional FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3.635	3,432	1,380	1,244	2,255	2,188
R-squared	0.009	0.113	0.020	0.217	0.016	0.083

Robust standard errors in parentheses

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

Table 6: Quantile regression results for birth weight

	(1)	(2)	(3)	(4)
Variables	q25	q50	q75	q95

SP stock-out	-6.612	-145.878*	-14.385	140.951
	(75.287)	(88.068)	(78.160)	(211.312)
Preterm delivery	-1,234.248***	-1,005***	-839.297***	-664.431***
	(147.144)	(84.068)	(142.100)	(79.315)
Birth interval	-30.761	-53.193**	-70.103**	-63.879
	(22.324)	(24.885)	(27.661)	(45.498)
Parity	27.091***	42.437***	30.660***	58.604***
	(6.873)	(8.339)	(11.706)	(13.856)
HIV status	-53.831	-24.585	-9.322	-143.827***
	(37.921)	(32.048)	(24.316)	(83.180)
Wealth index	-16.671	24.149*	19.430*	34.342
	(14.469)	(14.568)	(11.607)	(29.312)
Education	11.048*	5.214	-1.043	2.445
	(5.640)	(5.086)	(4.356)	(10.340)
Work status (working)	44.471*	37.701	25.519	26.897
	(27.568)	(27.123)	(21.078)	(59.775)
Constant	2,621.045***	3,010.515***	3,452.378***	3,811.665***
	(78.737)	(61.303)	(53.249)	(125.803)
Observations	3,432	3,432	3,432	3,432

Bootstrapped standard errors (200 replications) in parentheses

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

Table 7: Quantile regression results for haemoglobin level

	(1)	(2)	(3)	(4)
Variables	q25	q50	q75	q95
SP stock-out	0.153	0.310	0.384	0.032
	(0.238)	(0.197	(0.202)	(0.272)
Currently pregnant	-1.285***	-1.323***	-1.475***	-1.241***

	(0.176)	(0.129)	(0.114)	(0.326)
BMI	0.026***	0.0244***	0.019**	0.004
	(0.008)	(0.007)	(0.010)	(0.012)
Birth interval	-0.204**	-0.196***	-0.281***	-0.422***
	(0.089)	(0.058)	(0.068)	(0.088)
Parity	0.002	0.019	-0.013	-0.013
	(0.018)	(0.058)	(0.024)	(0.031)
HIV status	-1.099***	-0.852***	-0.868***	-0.574***
	(0.102)	(0.094)	(0.088)	(0.224)
Wealth index	-0.094*	-0.004	0.010	-0.045
	(0.052)	(0.035)	(0.045)	(0.052)
Education	0.009	0.000	-0.002	-0.005
	(0.014)	(0.013)	(0.014)	(0.018)
Work status (working)	0.011	-0.068	0.003	0.097
	(0.076)	(0.064)	(0.059)	(0.101)
Constant	11.649***	12.847***	13.888***	15.610***
	(0.262)	(0.184)	(0.269)	(0.302)
Observations	3,929	3,929	3,929	3,929

Bootstrapped standard errors (200 replications) in parentheses

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

6. Limitations of the study

Although the paper contributed to the body of knowledge on drug stock-outs and health outcomes in Zimbabwe, several limitations are worth mentioning.

The displacement of the cluster GPS coordinates in the DHS data was a limitation in linking the clusters to facilities. The displacement might distort the location, which may result in errors when linking the DHS and drug stock-out data. Linking the two datasets also assumes that the women were using one facility during pregnancy, even though there is at least one facility servicing the cluster. This eliminates the possibility of pregnant women receiving antenatal care from at least one facility. Thus, merging stock-out and

health outcomes data over space and time is also a limitation. DHS captures information for the entire year, which includes the time when malaria is at its peak and off-peak, which might result in underreporting of malaria's effects on the health outcomes of vulnerable groups in Zimbabwe. Like other surveys, DHS is prone to selection bias, non-response bias, and recall bias.

7. Conclusion

Drug stock-outs are the evidence of health system's failure to provide safe and affordable services to people in times of need. Given the frequent unavailability of drugs at health facilities in most developing countries, it is important to understand their effects on health outcomes. Therefore, this paper examined the extent and the effects of malaria prophylaxis stock-outs on the health outcomes of pregnant women and their neonates in Zimbabwe.

Zimbabwe is a malaria-endemic country and ensuring the availability of SP doses is important in reducing the negative effects of malaria on mothers and their neonates. However, the paper indicated that frequent malaria prophylaxis stock-outs at the facilities are prevalent. Regional disparities in drug stock-out exist in Zimbabwe, where other districts experience more drug stock-outs than others. Therefore, this presents missed opportunities for improving health outcomes and well-being. Malaria prophylaxis stock-outs were prevalent in Zimbabwe and significantly explained the low birth weight and maternal anaemia. This shows that SP doses were effective in improving birth and maternal health outcomes and not receiving these drugs increases the likelihood of malaria infections, therefore, compromising the health outcomes for the vulnerable population. Malaria prophylaxis stock-outs affect neonates with average birth weight, thus pushing them towards the lower end of normal birth weight, which is prone to developmental disabilities. Therefore, there is a need to ensure the availability of SP drugs at the facility level to improve their uptake during antenatal care visits. The paper recommended that policymakers should invest in pharmaceutical information systems and stock ordering systems to prioritise the prevention of malaria as proposed in the Sustainable Development Goals. There is also a need to improve the financial and administration of resources to enhance the procurement and delivery of drugs. Thus, improving the provision of safe, affordable and quality malaria control services in Zimbabwe.

Appendix A: Zimbabwean map

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