LUND UNIVERSITY
School of Economics and Management

Master's Programme in Economic Growth, Population and Development
Economic Demography Track

Spatial Accessibility, Institutional Delivery and Timely Initiation of Breastfeeding:

Evidence from Four Sub-Saharan African Countries

by

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Abstract: This thesis examines the relationship between spatial accessibility, institutional delivery and timely initiation of breastfeeding in Nigeria, Ghana, Tanzania and Zambia. It uses recent DHS data combined with OpenStreetMap data on health facilities and roads to construct spatial accessibility measures, including distance to the nearest health facility, distance to major roads and combined accessibility typologies. Logit models are used to analyse two questions: whether spatial accessibility is associated with institutional delivery, and whether place of delivery is associated with breastfeeding initiation within one hour after birth. The results show that spatial accessibility is associated with institutional delivery in all four countries, but the spatial dimension most strongly associated with delivery differs across contexts. Institutional delivery is positively associated with EIBF in all four countries, whereas caesarean section is negatively associated with EIBF. Together, the country-specific associations are consistent with the proposed service-use pathway.

Keywords: Spatial accessibility; Institutional delivery; Breastfeeding; Caesarean; DHS

EKHS02
Master's Thesis (15 credits ECTS)
May 2026
Supervisor: Luciana Quaranta
Examiner: Jaco Zuijderduijn
Word Count: 16106

Acknowledgements

I would like to thank Luciana Quaranta, who supervised my master's thesis work over the past two years. Her warm and generous support was essential for the completion of this thesis. She encouraged my interests and progress, and patiently guided me even when I asked basic questions. I believe that her help means more than this thesis itself. I will continue to benefit from her guidance in my future studies, work and life.

I would also like to express my gratitude for the last two courses I took, Data Management for Research and Geographical Information Systems for Economic History. The teachers not only taught us knowledge and practical skills, but also encouraged us to learn, reflect and think independently. These courses provided me with useful skills for my thesis, helped me make my own contribution during the research process, and encouraged me to continue doing meaningful research that can provide more convincing evidence for issues related to economic demography. During the past almost two years, I have worked hard to achieve the expected learning outcomes, overcome different difficulties, and make progress. Beyond academic knowledge, I have also gained friendship and many valuable life experiences.

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1 Introduction

1.1 Research Problem

Breastfeeding is crucial for infant survival, health and development in early childhood. World Health Organization (WHO) advises that breastfeeding should start within the first hour after birth (World Health Organization 2023). Early initiation of breastfeeding (EIBF) helps newborns receive immune components of breast milk soon after birth, and it is associated with a lower risk of neonatal mortality. Evidence from low- and middle-income countries showed that starting breastfeeding later than the first hour was linked to about a twofold higher risk of death during the neonatal period, compared with initiation within the first hour (Khan et al. 2015). Evidence on breastfeeding more broadly also shows protective effects against infectious illness and death, including diarrhoea and pneumonia, with especially important benefits in low-income settings (Lamberti et al. 2011; Lamberti et al. 2013; Victora et al. 2016). However, despite longstanding global recommendations, EIBF remains below optimal levels in many low- and middle-income countries, including in sub-Saharan Africa (Hamer et al. 2022; Issaka et al. 2017). Delayed initiation is not always a simple matter of maternal choice: caesarean delivery, maternal or infant health problems, inadequate support from health workers, and misconceptions about breastfeeding can all delay breastfeeding beyond the first hour.

Breastfeeding initiation timing is closely related to childbirth care. Although planned home births can be supported by professional midwives when maternity care and referral systems are well connected, health facility delivery remains an important strategy for ensuring professional care during childbirth in many low- and middle-income countries, especially when obstetric or newborn complications require equipment, supplies, emergency care or referral (Brocklehurst et al. 2011; Campbell & Graham 2006; Tura et al. 2013). Health facility delivery may also support early breastfeeding. The revised Baby-Friendly Hospital Initiative includes early skin-to-skin contact after birth and assistance with breastfeeding initiation as key practices in maternity and newborn care (Raihana et al. 2021; World Health Organization & UNICEF 2018).

At the same time, women's opportunities to give birth in a health facility are not equally distributed. Place of delivery is shaped by socioeconomic and cultural factors, including education, household resources and family expectations, as well as by structural access conditions such as facility availability, distance to care and transport conditions (Bohren et al. 2014; Gabrysch & Campbell 2009; Kifle et al. 2018; Moyer & Mustafa 2013).

Spatial accessibility is an important structural factor connecting the geographical environment and the use of maternal and child health services. For delivery services, besides whether health facilities exist, whether women can reach facilities in time is also important (Thaddeus

& Maine 1994; Gabrysch & Campbell 2009). The spatial accessibility focused on in this study mainly includes two dimensions. First, the spatial distribution of health facilities is measured by the distance from women's place of residence to the nearest health facility, since longer distance is usually associated with greater travel time, transport cost and uncertainty on the way. Second, the distance to major roads is used to capture women's connection to the main transport network, because road access can influence how easily they reach health services, especially in areas where facilities are not nearby. Global research on healthcare accessibility also shows that geographical access to healthcare depends on facility locations, road networks, transport modes and travel time, rather than simply on the presence of health facilities (Weiss et al. 2020). This issue is particularly important in sub-Saharan Africa, where remote communities often have longer journeys to health services and more limited road connections (Falchetta et al. 2020).

Existing evidence generally suggests a positive association between institutional delivery and EIBF across sub-Saharan Africa (Alzaheb 2017; Ameyaw et al., 2023; Appiah et al., 2021; Birhan et al., 2022). However, this relationship is not consistent across all contexts. Studies from Bangladesh and Malawi suggest that the association between institutional delivery and EIBF may vary across settings, and may also be related to caesarean section, antenatal care (ANC) utilization and birth order (Ali et al., 2020; Chipojola et al., 2020). These mixed findings suggest that the relationship between institutional delivery and EIBF should be examined within specific national contexts. UNICEF and WHO (2018) show that, among 58 countries with trend data, institutional delivery increased from 53% to 71% between 2005 and 2017, while EIBF increased only from 45% to 51%, highlighting the importance of continuing to study this issue using the latest data.

1.2 Aim and Scope

This study focuses on Nigeria, Ghana, Tanzania and Zambia. These four countries are all located in sub-Saharan Africa, but they provide useful contrasts in maternal and newborn health, facility delivery, breastfeeding practices and spatial accessibility. Nigeria represents a high-burden West African setting with low facility delivery and low EIBF. Ghana provides a contrasting West African case, with much higher facility delivery coverage and a different maternal health financing background. Tanzania represents an East African setting where facility delivery is relatively common, but distance to health facilities remains a reported barrier (Ministry of Health Tanzania et al. 2023). Zambia also has high facility delivery coverage, but geographical and socioeconomic inequalities remain relevant (Zambia Statistics Agency, Ministry of Health Zambia & ICF 2024). Comparing these countries helps examine whether the theoretical pathway from spatial accessibility to institutional delivery and then to EIBF operates in similar ways across countries, or whether different countries face different spatial accessibility barriers.

Existing studies have often examined the association between spatial accessibility and institutional delivery separately from the association between place of delivery and EIBF.

This study brings these two associations into the same comparative framework and treats them as adjacent stages in a proposed service-use pathway.

In addition, DHS-based studies commonly measure access through women's self-reported assessment of whether distance is a major problem. These reports are valuable because they may reflect women's experienced difficulty, including transport availability and household resources, while externally derived distances provide a standardized measure of geographic proximity; the two indicators are therefore complementary rather than interchangeable (Dotse-Gborgbortsi et al. 2022).

This study introduces external geographical data from OpenStreetMap (OSM) to construct actual distance variables for spatial accessibility, and places spatial accessibility, institutional delivery and EIBF within the same analytical framework. This design connects geographical constraints before childbirth with newborn feeding practices that occur after birth. By combining recent DHS individual data with OSM on health facilities and roads, it first analyses whether spatial conditions are associated with institutional delivery, and then analyses whether place of delivery is associated with EIBF as an important health outcome, thereby connecting structural geographical conditions, health service utilization and early newborn health practices. At the same time, this study compares Nigeria, Ghana, Tanzania and Zambia, which also helps to show whether the same theoretical pathway presents the same pattern under different levels of institutional delivery, road conditions and maternal and child health contexts.

Research Question 1 (RQ1): How is spatial accessibility associated with institutional delivery in Nigeria, Ghana, Tanzania and Zambia?

Research Question 2 (RQ2): How is place of delivery associated with EIBF in Nigeria, Ghana, Tanzania and Zambia?

1.3 Outline of the Thesis

The thesis is structured as follows. Section 2 introduces the research background. Section 3 presents the theoretical framework. Section 4 reviews previous research. Section 5 introduces the data, variables and sample. Section 6 explains the empirical methods. Section 7 presents the results. Section 8 discusses the findings. Section 9 outlines the study limitations. Section 10 concludes the thesis.

2 Context

2.1 Maternal and Child Health and Breastfeeding Practices in Sub-Saharan Africa

Sub-Saharan Africa remains a central region for understanding maternal and newborn health challenges. In 2023, the world recorded about 260,000 deaths related to pregnancy or childbirth, and 70% of these deaths occurred in sub-Saharan Africa. The burden is not evenly distributed within the region. West Africa had a maternal mortality ratio (MMR) of 691 deaths per 100,000 live births in 2023, while East Africa had a lower level of 263, although both remained above the Sustainable Development Goal (SDG) target of below 70 (World Health Organization et al. 2025). The four countries in this study show this regional contrast clearly. Nigeria had the highest MMR, at 993 per 100,000 live births, and around 75,000 maternal deaths in 2023. Ghana was much lower, at 234, which is relatively moderate within West Africa, while Tanzania was 276 and Zambia was 85 (World Health Organization et al. 2025). These figures show that the four countries are located in the same broad region, but they face different levels of maternal health risk.

Child survival indicators show a similar pattern. Nigeria has the highest child mortality level among the four countries, with an under-five mortality rate of 116 per 1,000 live births, an infant mortality rate of 70, and a neonatal mortality rate of 39. The corresponding figures are lower in Ghana, Tanzania and Zambia: 36, 28 and 18 in Ghana; 37, 29 and 20 in Tanzania; and 48, 35 and 21 in Zambia (UNICEF Data 2026). These differences matter for this study because the neonatal period is the most vulnerable stage in a child's life, and the time around birth is also the time when delivery care, newborn care and early feeding practice are closely connected (World Health Organization 2024).

Breastfeeding practices also differ across the four countries. Exclusive breastfeeding is particularly low in Nigeria, while Ghana, Tanzania and Zambia show relatively higher but still incomplete coverage (UNICEF Data 2026). This suggests that breastfeeding is not uniformly weak across all countries, but the first hour after birth remains a specific point where country differences are clear. The proportion of children put to the breast within one hour after birth is 36% in Nigeria, 58% in Ghana, 70% in Tanzania and 68% in Zambia (UNICEF Data 2026). This means that the four countries not only cover different burdens of maternal and child mortality, but also cover different levels of early feeding practices. Nigeria combines a high maternal and child mortality burden with a relatively low level of EIBF. Ghana has lower child mortality and a higher EIBF level than Nigeria within West Africa. Tanzania and Zambia have higher levels of EIBF, but maternal mortality, child mortality and service inequality problems still exist.

2.2 Place of Delivery and the Use of Institutional Delivery Services

Place of delivery is an important entry point for understanding the use of maternal and child health services in sub-Saharan Africa. Delivery is a high-risk period for both mothers and newborns, from labour and childbirth to the early postnatal period. Globally, skilled attendance at birth is 86%, but sub-Saharan Africa still lags behind: in 2023, 74% of births were attended by skilled personnel and 64% took place in health facilities (UNICEF Data 2024).

The use of institutional delivery is influenced by multiple factors, including the availability and accessibility of health facilities, perceived quality of care, household decision-making and previous contact with health services (Gabrysch & Campbell 2009; Moyer & Mustafa 2013; Bohren et al. 2014). Differences between the four countries therefore reflect not only variation in institutional delivery levels, but also variation in maternal healthcare infrastructure and access conditions. Women's limited decision-making autonomy, dependence on husbands and relatives, socio-cultural norms around childbirth, long distances and lack of money for transport can all discourage facility delivery (Sialubanje et al. 2015). This suggests that geographic accessibility should be interpreted together with household and cultural conditions.

Among the four study countries, Nigeria remains the lowest-coverage case. The 2024 Nigeria Demographic and Health Survey (NDHS) places Nigeria well below the other three countries: 43% of births were facility births and 46% had skilled attendance, although both indicators have improved compared with earlier NDHS rounds (Federal Ministry of Health and Social Welfare, National Population Commission & ICF 2025). Some women's reluctance to use primary health centres is linked to doubts about whether facilities have enough staff, drugs and equipment, or whether services are reliably available when labour begins (Udenigwe et al. 2021; Akinsola et al. 2025). Nigeria has a large absolute number of health facilities, but the supply is low relative to population size: Federal Ministry of Health estimates cited in health-system infrastructure work suggest about 1.4 facilities per 10,000 people, and the facility stock is dominated by primary-level facilities (SEforALL 2022). Nigeria's low institutional delivery coverage occurs in a context of barriers to service use and limited health facility supply relative to its population.

Ghana is also located in West Africa, but much closer to a high-coverage setting. In the 2022 Ghana Demographic and Health Survey (GDHS), 86% of live births were facility births and 88% had skilled attendance (Ghana Statistical Service & ICF 2024). Ghana's higher use of facility delivery occurs within a financing context that includes free maternal care under the National Health Insurance Scheme (Agbanyo 2020; Kofinti, Asmah & Ameyaw 2022). Facility supply is also denser than in Nigeria, Ghana therefore provides a useful contrast to Nigeria: both are West African countries, but they differ in institutional delivery coverage, health financing arrangements and facility density (Countdown to 2030 2025). This shows that West Africa is not simply a low-service-coverage region.

In Tanzania, institutional delivery has become relatively common. The 2022 Tanzania Demographic and Health Survey and Malaria Indicator Survey (TDHS-MIS) reports that 81% of live births occurred in health facilities and 85% were attended by skilled personnel, while home delivery has declined markedly over the past three decades (Ministry of Health Tanzania et al. 2023). This change is consistent with Tanzania's long-term expansion of primary healthcare infrastructure through the Primary Health Services Development Programme, MMAM, 2007–2017, which aimed to expand and improve primary facilities and district hospitals (Ministry of Health and Social Welfare Tanzania 2007). However, higher national coverage does not mean that all women use the same type or level of delivery care. The 2023 Service Availability and Readiness Assessment lists 9,221 health facilities, but most were dispensaries or health centres, with 431 hospitals (Ministry of Health Tanzania 2023). Rural institutional delivery has improved, but the remaining non-facility deliveries are still more likely to be found among rural and less advantaged groups (Countdown to 2030 2025).

Zambia also has high institutional delivery coverage, but this high coverage coexists with questions about rural service capacity and socioeconomic inequality. The latest DHS evidence shows that facility delivery is common, but use of delivery services still varies by background characteristics such as residence and household resources (Zambia Statistics Agency, Ministry of Health Zambia & ICF 2024). Zambia has about 1.72 health facilities per 10,000 people, slightly below the commonly used benchmark of 2 facilities per 10,000 people. Zambia's removal of user fees in rural public and mission facilities was intended to lower financial barriers to basic health service use, including delivery care (Chama-Chiliba & Koch 2016; Renard 2022). Facility density is reported to be higher in rural than urban areas, but this does not necessarily mean that rural facilities have sufficient equipment, supplies or staff for good-quality care (Government of the Republic of Zambia et al. 2025).

2.3 Spatial Accessibility, Transport Conditions and Geographical Environment

All four study countries face spatial accessibility problems, but these problems take different forms. In Nigeria, the main background is the combination of a very large population, strong regional differences and weak rural road access. The 2024 NDHS also shows that access to healthcare remains difficult for many women: 55% of women aged 15–49 reported at least one problem in accessing healthcare when sick, and distance to a health facility was reported as a problem by 25% (Federal Ministry of Health and Social Welfare, National Population Commission & ICF 2025). Nigeria has a large road network in absolute terms, with about 195,000 km of classified roads. Based on Nigeria's land area, this is roughly 21 km of road per 100 km², close to the Sub-Saharan African average of about 20.4 km per 100 km² reported in the Africa Infrastructure Country Diagnostic study (Gwilliam et al. 2008; World Bank 2020). However, rural road access remains limited. Nigeria's Rural Access Index (RAI) is estimated at 25.5%, meaning that around three-quarters of the rural population, or about 92.5 million people, do not live within 2 km of a road that stays accessible year-round. Rural accessibility was also uneven across the country, with better access in several southern states and much weaker access in the north-east (World Bank 2019). In a country where institutional delivery remains relatively low, this road background provides useful context for understanding spatial differences in access to delivery services, together with the distribution of health facilities and other service-use barriers.

The 2022 GDHS also shows that healthcare access problems are more common among rural women: 63% of rural women aged 15–49 reported at least one problem accessing healthcare when sick, compared with 47% of urban women; distance to a health facility was reported as a problem by 22% of women overall (Ghana Statistical Service & ICF 2024). Ghana has a relatively extensive road network, estimated at about 94,203 km, but 73% of it remains unpaved (Ministry of Roads and Highways Ghana 2023). Transport conditions still vary across regions. In the Upper West Region, 61% of the population could reach primary facilities within the recommended standard, compared with 81% for secondary facilities and 48% for tertiary facilities (Korah, Nunbogu & Ahmed 2023). Ghana's 2022 health system assessment points to a similar issue: ambulance engagement times were shorter in some regions partly because facilities were denser and roads were better (Ministry of Health Ghana 2023). This suggests that road quality and referral distance may still matter for access to appropriate care.

Tanzania and Zambia represent contexts in Eastern and Southern Africa where rural geography and transport connections remain relevant. In the 2022 TDHS-MIS, 29% of women reported distance to a health facility as a healthcare access problem. Reporting at least one access problem was also more common among rural women than urban women, 56% compared with 39% (Ministry of Health Tanzania et al. 2023). Tanzania has a total road network of about 181,190 km, including 37,435 km of national roads and 144,430 km of district, urban and feeder roads (Tanzania National Roads Agency 2024). In Tanzania, the national and regional road network connects major towns and district centres, but only about one quarter of the rural population was connected to roads in good or fair condition (World Bank 2016). The Roads to Inclusion and Socioeconomic Opportunities (RISE) project also shows that rural road access remains uneven: in the project areas, only 48% of the rural population had access within 5 km to roads in good condition at baseline, and only 45% of district rural roads were classified as being in good or fair condition. Its activities are centred on selected rural road improvements, local bottleneck removal and maintenance of district roads, which is closely related to how rural communities connect to larger service and transport networks (World Bank 2021).

Zambia shows a stronger main-road connectivity problem. The 2018 Zambia Demographic and Health Survey (ZDHS) reports that 51% of women aged 15–49 had at least one problem accessing healthcare, with a higher level among rural women than urban women, 62% compared with 39%; distance to a health facility was one of the most frequently reported barriers, at 29% (Zambia Statistics Agency, Ministry of Health Zambia & ICF 2019). The structure of Zambia's road network is relevant for understanding access to major roads. The country's gazetted road network is about 67,671 km, but trunk and main roads together account for only 6,817 km, while much of the network consists of district and feeder roads (Road Development Agency 2022a). Zambia's road-sector strategy also notes that parts of the Core Road Network are in poor condition and that maintenance projects have often been delayed (Road Development Agency 2022b).

In this context, distance to major roads is a useful way to capture broad differences in connection to the main transport network, especially in rural areas where settlements may be far from higher-level road corridors.

3 Theory: Conceptual Framework from Structural Conditions to Health Practice

Although EIBF occurs within one hour after birth, its formation mechanism is not limited to this short time window, but also includes broader spatial accessibility, delivery environment and socio-spatial structure. The theoretical logic of this study is based on the basic framework that structural conditions shape behavioral choices, and behavioral choices further influence health practices (McLeroy et al., 1988; Andersen, 1995). Specifically, whether women can initiate breastfeeding in time depends not only on their personal willingness or knowledge level, but is also jointly influenced by whether they can enter the healthcare service system, the delivery process, and the postnatal environment.

This is highly consistent with Andersen's Behavioral Model of Health Services Use. Andersen explains health service utilization as the result of the joint effects of predisposing factors, enabling factors and need factors. Among them, enabling factors include not only resource conditions at the individual and household levels, but also healthcare service supply, facility distribution and service accessibility at the community level (Andersen, 1995). This model especially emphasizes that health service utilization is not completely determined by individual preferences, but is a behavioral outcome formed under the constraints of institutional resources and social structures.

Based on this theoretical framework, this study treats spatial accessibility as a community-level structural enabling condition, and measures women's realistic possibility of entering the healthcare service system through distance to health facilities and distance to roads. Therefore, spatial accessibility does not directly determine EIBF, but indirectly shapes breastfeeding behavior by influencing whether women can achieve institutional delivery, and through the support and services provided by institutional delivery. On this basis, this study further combines the perspectives of spatial inequality and social inequality to discuss the interaction between individual characteristics and spatial constraints, and how compositional effects and contextual effects jointly influence women's delivery behavior and postnatal health practices.

3.1 Spatial Accessibility as Structural Factors

Spatial accessibility refers to the difficulty or ease with which people can reach service opportunities in geographic space. In healthcare research, this usually involves the spatial distribution of facilities, population location and transport conditions (Guagliardo 2004; Higgs 2004). Penchansky and Thomas's framework of service accessibility understands access as the fit between users and the service system, including dimensions such as whether services exist, whether they are reachable, whether they are affordable, and whether they are acceptable (Penchansky and Thomas, 1981). In this study, distance to health facilities mainly reflects the spatial location of service supply, while distance to roads mainly reflects the condition for communities to enter the transport network. They correspond respectively to two different aspects of spatial accessibility: “whether services exist” and “whether services are easy to reach.”

The Three Delays Model in the field of maternal health further explains the importance of spatial accessibility (Thaddeus and Maine, 1994). Thaddeus and Maine divide delays in maternal treatment into three stages: delay in deciding to seek care, delay in reaching a health facility, and delay in receiving appropriate care after arrival. Spatial distance and road connection mainly correspond to the second type of delay, but they may also influence the first type of delay, because long distance, transport difficulty and high travel costs reduce the feasibility for families to choose institutional delivery (Thaddeus and Maine, 1994). The first research question of this study is exactly to analyse whether structural factors such as the distribution of health facilities and road conditions are associated with the behavioral choice of institutional delivery, that is, whether women's likelihood of entering an institutional delivery environment decreases when their residential location is far from health facilities or major roads.

3.2 Place of Delivery as Constrained Behavioral Choices

Institutional delivery can be regarded as women's choice of medical services, but this choice is not completely free. Constrained choice theory emphasizes that even if individuals have the ability to make behavioral choices, they are always jointly constrained by external conditions such as resource distribution and social institutions (Bird and Rieker, 2008). According to Simon's theory of bounded rationality, real-world decision-making is not based on complete information or unlimited computational ability, but often relies on satisfactory choices under constraints (Simon 1955). Simon later distinguished procedural rationality from substantive rationality, emphasizing that decision processes matter when individuals face limited information and complex environments (Simon 1976). For women, when deciding whether to go to a health facility for delivery, they do not simply make abstract calculations based on medical benefits, but make “feasible” rather than “optimal” choices under limited information, limited transport conditions, limited medical resources and existing social backgrounds. Gabrysch and Campbell (2009) also show that distance and transport barriers are important deterrents of delivery service use. In the Three Delays framework, these barriers mainly correspond to delays in reaching care, but they may also affect the earlier decision to seek care (Thaddeus and Maine 1994).

3.3 Timely Initiation of Breastfeeding as Health Practices

Although the time window in which it occurs is very short, EIBF is a health practice formed through the interaction between individual behavior and the social environment. Amir (2011), in a social theory study on infant feeding, points out that breastfeeding is not an isolated behavior, but is influenced by factors such as the social environment, cultural habits and economic level. For example, low-income families are more inclined to regard feeding as a practical aspect related to survival, while high-income families pay more attention to understanding breastfeeding from scientific and nutritional perspectives. According to Bourdieu's (1984) theory of taste and social distinction, food is an expression of gender, social class and identity. For women living in communities filled with anti-breastfeeding discourse or where formula feeding is popular, they are more likely to give up breastfeeding. Even if women recognize the importance of breastfeeding, knowledge cannot necessarily be transformed into action (Amir, 2011).

From the perspective of the Socio-Ecological Model, breastfeeding behavior is jointly influenced by multiple progressive levels: individual, interpersonal, organizational, community and policy environments (Bronfenbrenner, 1979; McLeroy et al. 1988). McLeroy et al. (1988) developed it into a framework focusing on environmental factors to explain health behavior, emphasizing the importance of interventions. The environment can have an important motivating effect and can positively influence the initiation of early breastfeeding. In health facilities, members of the medical team support EIBF by providing breastfeeding education, postnatal care practices, encouraging skin-to-skin contact, and rooming-in (World Health Organization & UNICEF 2018; Pérez-Escamilla et al. 2016). In short, hospitals can provide multiple positive supports for EIBF at the organizational level.

At the same time, caesarean section mainly occurs inside health facilities and is sometimes a necessary measure to save the lives of mothers and infants, but it may have a negative relationship with EIBF. Caesarean may delay breastfeeding initiation through postoperative recovery, mother–infant separation, anaesthesia-related care routines, or infant monitoring. Therefore, health facilities may provide a supportive environment for EIBF, but the delivery process within facilities can also lead to different breastfeeding outcomes (Prior et al. 2012; Hoang Nguyen et al. 2020; Getaneh et al. 2021).

3.4 Contextual versus Compositional Effects

Discussions about regional differences usually revolve around compositional effects and contextual effects. In the discussion of “places or people,” Macintyre, Maciver and Sooman (1993) proposed that regional health differences may come from the socioeconomic composition of residents themselves, or may come from the shaping of health opportunities by regional environments (Macintyre, Maciver and Sooman, 1993). The former emphasizes “what kind of people live in a place,” while the latter emphasizes “what kind of health conditions a place itself provides or restricts.” This framework moves health differences away from purely individual explanations, and requires researchers to consider both population composition and local environment as two types of mechanisms.

Compositional effects emphasize that differences in health service utilization or health behaviors between regions may first come from differences in the individual and household characteristics of residents. From this perspective, regional differences should not be interpreted immediately as the independent effect of places themselves. They may also reflect the uneven concentration of individual and household disadvantages across areas, such as poverty, education, family resources and health-related experience (Sloggett and Joshi, 1994).

Contextual effects emphasize that the local environment itself may also shape health service utilization and health practices. Macintyre, Maciver and Sooman (1993) argued that in the contextual perspective, area-level variables are not only substitutes for missing individual information. They can also represent the material, service and social conditions provided by places themselves. More broadly, contextual effects can be understood as the ways in which area-level material resources, service environments and social conditions structure health opportunities, beyond the characteristics of individuals living in those areas (Diez Roux, 1998, 2001; Macintyre, Ellaway and Cummins, 2002).

The theoretical distinction between compositional effects and contextual effects is not to choose between individual and regional factors as causes, but to show that health service utilization is constrained by both types of mechanisms at the same time. In multilevel health research, this distinction provides a basis for examining whether area-level conditions have explanatory value beyond individual socioeconomic characteristics (Pickett and Pearl 2001). Duncan, Jones and Moon (1998) pointed out that compositional effects and contextual effects may also have heterogeneity: the meaning of contextual conditions is not necessarily the same for all individuals. That is to say, it is also necessary to further consider the interaction between individual characteristics and spatial constraints. The same regional environment may produce constraints of different strengths for different socioeconomic groups.

3.5 Spatial Inequalities

According to neighborhood effects, community and regional environments can influence health behaviors through multiple pathways such as resource supply, institutional support, social norms and the physical environment (Diez Roux, 2001). This influence is reflected not only in differences in material resources, but also in inequality in spatial opportunity structures. Galster and Killen (1995) pointed out that the spatial environment determines what kinds of resources, institutions and social opportunities individuals can access, and therefore spatial inequality is essentially also opportunity inequality. For healthcare behaviors, the distribution of health facilities, road conditions, transport networks and service accessibility all affect individuals' realistic ability to enter the healthcare system. Stafford and Marmot's (2003) study shows that the adverse effects of deprived communities may be stronger for deprived individuals, because individuals with fewer resources are more dependent on local public resources and community services (Stafford and Marmot, 2003).

4 Previous Research

4.1 Spatial accessibility and facility delivery

The choice of place of delivery has always been closely related to maternal and child outcomes. Deliveries attended by skilled birth attendants in health facilities have lower maternal morbidity and mortality than home deliveries, and delivery in health facilities also plays a crucial role in improving newborn survival (Kifle et al., 2018). The review by Gabrysch and Campbell (2009) pointed out that the influencing factors of institutional delivery, or skilled attendance at delivery, can generally be grouped into four categories: sociocultural factors, perceived benefits or necessity of skilled attendance, economic accessibility, and physical accessibility. Among them, the farther the distance to health facilities, the lower the likelihood that women use institutional delivery services, and this effect often overlaps with problems such as poor transport conditions, low road quality and difficulty travelling at night.

GIS-based studies have already contributed to the measurement of maternal healthcare access. A study in Kenya has used travel-time modelling to evaluate spatial access to maternal health facilities and identify underserved areas (Ouko et al. 2019). Tanou et al. (2021) provide a example of combining DHS and GIS data: in Benin, distance to the nearest health centre were negatively associated with ANC use, institutional delivery and skilled birth attendance. Fatima et al. (2025), based on a study in Bangladesh, also pointed out that each 1 km increase in the distance between the mother's residence and the health facility is associated with about a 20% decrease in the likelihood of facility-based normal delivery.

By contrast, a study on rural India pointed out that economic constraints are more important than accessibility to health facilities, both in explaining why women did not choose institutional delivery and in explaining the choice between public and private facilities (Kesterton et al., 2010). Furthermore, a study of the free maternal healthcare programme in Cross River State, Nigeria, showed that after the removal of direct fees, pointed out that indirect costs, geographical barriers and lack of trust in the health system still limited the policy effect (Edu et al., 2017). However, the public–private distinction should be interpreted cautiously. Multi-country DHS evidence from SSA suggests that facility delivery was associated with higher odds of EIBF than home delivery, while within facility births there was no clear evidence that public or private sector delivery was associated with EIBF differently (Bergamaschi, N., Oakley, L. and Benova, L. 2019).

There have also been studies that have analyzed how spatial accessibility affects facility delivery within the countries studied in this thesis. Banke-Thomas et al. (2024), in a spatial analysis of the 15 largest cities in Nigeria, showed that even in environments usually considered to be advantaged, the time for women to reach functional emergency obstetric care facilities may still be long, and there are significant differences between different areas.

For Ghana, existing research shows that higher institutional delivery coverage does not mean that spatial barriers have disappeared. Dotse-Gborgbortsi et al. (2022), based on the 2017 Ghana Maternal Health Survey and geographical modelling, found that women who self-reported that "distance is a big problem" did indeed have longer modelled travel time, while poor, rural and less educated women were more likely to report distance barriers.

Rural research in Tanzania shows that geographical distance not only affects whether obstetric care can be obtained, but is also related to the risk of obstetric death. In rural southern areas, women living more than 35 km from a hospital had a clearly higher direct obstetric mortality rate than those living within 5 km of a hospital (Hanson et al., 2017). Kohi et al. (2018), in a qualitative study in the Lake Zone region of Tanzania, showed that the timing of going to hospital is often limited by transport availability and distance. Some women delayed departure because of transport difficulties, and even delivered on the way to hospital.

Gabrysch et al. (2011), based on DHS and health facility GIS data in rural Zambia, found that each doubling of the distance to a delivery service facility was associated with about a 29% decrease in the odds of health facility delivery. Research on remote rural areas in Zambia also found that even though the government recommends that all women deliver in health facilities, women living more than 10 km from a health facility may still give birth at home or on the way to a facility because of transport difficulties and cost burdens (Scott et al., 2018). Another study using the phased implementation of the policy found that after the removal of user fees, the probability of health facility delivery increased by 43% but these positive effects weakened as the distance from the household to the nearest health facility increased (Renard, 2022). This result is highly related to the spatial accessibility focused on in this study: fee reduction is effective, but distance can still weaken policy benefits.

Overall, this literature shows that geographic access matters for institutional delivery, but the size and consistency of this relationship differ across settings. This makes it useful to examine spatial accessibility separately across countries rather than assuming that one regional pattern applies to all settings. Whatsmore, these studies mainly focus on access to delivery care itself. They do not usually extend the analysis to post-birth practices such as EIBF.

4.2 Place of delivery, c-section and early initiation of breastfeeding

EIBF is closely related to the newborn health. The NEOVITA study, based on a pooled analysis of data from three large trials in Ghana, India and Tanzania, found that compared with initiating breastfeeding within one hour after birth, delaying breastfeeding initiation to 2–23 hours after birth was associated with a higher risk of neonatal mortality (NEOVITA Study Group, 2016). A multilevel modelling study based on Demographic and Health Survey

(DHS) data from 32 sub-Saharan African countries estimated that the pooled level of EIBF in the region was about 57%, indicating that this practice has still not been fully achieved at the regional level (Birhan et al., 2022). Recent Ethiopian evidence shows that EIBF has clear spatial clustering and that the strength of determinants can vary across regions, but these studies mainly model the spatial pattern of EIBF itself (Hailegebreal et al. 2022; Tebeje et al. 2024).

Regarding the relationship between place of delivery and EIBF, existing studies generally support the positive role of health facility delivery, but also suggest that this relationship has contextual differences. Appiah et al. (2021), based on DHS data from 29 countries, found that compared with home delivery, women who delivered in health facilities were more likely to initiate breastfeeding within one hour after birth, and delivery assisted by health professionals was also significantly associated with a higher probability of EIBF. However, using the 2016 Nepal DHS, Hollow et al. (2023) found that health facility delivery was not a significant explanatory variable for EIBF.

In the context of sub-Saharan Africa, EIBF is also closely related to socioeconomic conditions and maternal characteristics. Alzaheb (2017) pointed out that higher birth order is usually associated with a higher probability of EIBF, which may mean that mothers with previous delivery and feeding experience are more likely to initiate feeding early after the newborn is born. Based on a systematic review and meta-analysis of 25 studies in Ethiopia, Habtewold et al. (2020) found that higher maternal and paternal education levels, higher household income, and married status were all significantly associated with a higher probability of EIBF. In Malawi, EIBF has certain spatial differences, for example, rural women were more likely to initiate breastfeeding in time, while women in the Central Region were less favourable for achieving early feeding initiation than women in the Northern Region, but health facility delivery was significantly associated with a higher probability of EIBF (Nkoka et al., 2019).

Alebel et al. (2017) pointed out that the likelihood of EIBF among mothers who delivered in health facilities was about 2.11 times that of mothers who delivered outside health facilities, providing strong comprehensive evidence for the idea that "entering institutional delivery is beneficial to early feeding initiation." Caesarean section is a factor that needs special consideration when explaining the relationship between institutional delivery and EIBF, because it usually occurs inside health facilities, but may delay breastfeeding initiation. Yisma et al. (2019), based on within-country analyses and a meta-analysis of DHS data from 33 sub-Saharan African countries, found that compared with vaginal delivery, caesarean section was significantly associated with reduced EIBF.

There have also been studies that have analyzed the relationship between place of delivery and EIBF within the countries studied in this thesis. Adewuyi et al. (2017), based on an analysis of the 2013 Nigeria DHS, found that in rural Nigeria, health facility delivery was significantly associated with a higher probability of EIBF, while this association was not obvious in urban areas. Using the 2014 GDHS, Seidu et al. (2020) also examined EIBF determinants in Ghana and showed that EIBF is associated with maternal, household, delivery place and health-service factors. Evidence from Northern Ghana pointed that partner support and exposure to breastfeeding information during pregnancy were positively associated with EIBF (Dubik and Amegah, 2021). Exavery et al. (2015), in a study in rural Tanzania, found that the proportion of EIBF was only 51%, and health facility delivery was significantly associated with a higher probability of EIBF. Kiwango et al. (2020), in a study in the Kilimanjaro region of northern Tanzania, found that the proportion of EIBF was 71.1%, higher than the national estimate for Tanzania, but the study also pointed out that in the Kilimanjaro region, most sociodemographic factors did not show significant associations with EIBF. Evidence from a private hospital in Tanzania shows that facility practices are modifiable: a quality-improvement programme combining staff training, antenatal education, immediate skin-to-skin contact after caesarean birth and dedicated lactation support increased EIBF from 22% to 84% (Osman et al. 2024). For Zambia, country-specific analytical evidence on EIBF determinants appears more limited than for Nigeria, Ghana and Tanzania. Zambia is mainly contextualized through multi-country SSA studies. In Ameyaw et al. (2023), Zambia formed part of the 11-country DHS sample, providing comparative evidence that facility delivery is generally associated with higher EIBF across sub-Saharan Africa.

In summary, geographic-access studies using GIS data have mainly focused on antenatal care or facility delivery, while EIBF studies have more often focused on place of delivery, caesarean section and maternal or household characteristics. Spatial studies of EIBF usually examine clustering and regional variation in EIBF rather than linking external measures of health facility and road access to delivery place and EIBF. This thesis extends this line of research by placing spatial accessibility, institutional delivery and EIBF in one pathway, using comparable recent DHS and geospatial data from Nigeria, Ghana, Tanzania and Zambia.

5 Data

5.1 Data and Study Sample

This study uses the Demographic and Health Surveys (DHS) as the main individual-level data source. DHS is a nationally representative household survey widely conducted in low- and middle-income countries. It uses standardized questionnaires to collect information related to population, health and nutrition, and has strong cross-country comparability. The women's individual questionnaire of DHS is for women of reproductive age aged 15–49, and includes variables such as birth history, maternal service utilization, postnatal care, infant and young child feeding practices, and maternal and child health (Croft, Marshall and Allen, 2018; The DHS Program). These information can support this study in analysing women's place of delivery and timely initiation of breastfeeding behavior.

This study selects four sub-Saharan African countries: Nigeria, Ghana, Tanzania and Zambia. First, all four countries have available DHS individual data and geographic coordinate data, which can support both maternal & child health analysis and spatial accessibility analysis. Second, the four countries are distributed in West Africa, East Africa and Southern Africa, and they have both common problems and clear differences in maternal and child health burden and spatial accessibility background. Therefore, they are suitable for cross-national comparisons. This study uses the latest and available datasets of each country, specifically including Nigeria DHS 2024, Ghana DHS 2022, Tanzania DHS 2022 and Zambia DHS 2024.

The main individual-level variables come from DHS Kids Recode (KR) files, such as place of delivery, breastfeeding, caesarean section, child sex, birth order, maternal age, maternal education, household wealth, urban-rural residence, region and antenatal care. After being cleaned and regrouped, these variables enter the final analysis data. They are first processed within each country, and then combined into a unified four-country analysis dataset. The DHS original weight variable v005 is converted into the probability weight wt = v005 / 1,000,000, and all descriptive statistics and regression models use this weight.

This study also uses three types of geographic data. First, this study uses the shapefile layer of the Geographic Data File in the DHS Geographic Datasets. In this file, DHSCLUST is used to identify the residential location of the sampling point where respondents are located. This layer is combined with external geographic data in QGIS, such as health facilities and roads, to calculate spatial accessibility variables. These variables are then merged into the individual sample based on DHSCLUST. To protect respondents' privacy, DHS randomly shifts the cluster coordinates. Urban clusters are displaced by up to 2 km, and rural clusters are usually displaced by up to 5 km, with about 1% of rural clusters may be displaced within 10 km (DHS Program, 2024). Although this may bring certain measurement error, it can still be used to identify accessibility differences. On the one hand, this study focuses on the relative differences in spatial accessibility, such as urban and rural areas, central and remote areas, areas with dense and sparse facilities, and so on. On the other hand, the random processing does not systematically move clusters according to the locations of health facilities or roads, so it mainly may introduce random error. Existing research on DHS coordinate displacement also points out that displacement affects the precise measurement of distance to the nearest facility or road, but its main problem is increasing the uncertainty of distance variables and possibly weakening the strength of estimates, rather than necessarily changing the direction of the relationship (Warren et al., 2016).

The second type of geographic data is DHS Geospatial Covariates, which contains ancillary data for DHS survey cluster locations, such as population, environment, and so on. This study mainly uses the travel time variable as a supplementary spatial accessibility indicator for RQ1. Its meaning is the estimated travel time from the DHS survey cluster to the nearest high-density urban centre, measured in minutes. Although it is not the travel time to the nearest health facility, it can reflect broader geographical remoteness, the degree of integration into transport networks, and the convenience of accessing service centres, thus providing a more comprehensive regional accessibility background.

The third type of geographic data comes from OpenStreetMap (OSM). OSM is an open geographic data source, in which different geographic objects are stored as points, lines or polygons, and their types and functions are recorded through attribute fields such as amenity. Its advantages are that the data access process is transparent, the data are updated relatively frequently, they can be matched with recent DHS datasets, and consistent data screening and processing standards can be applied across different countries. This study uses healthcare facility point data and road line data from OSM to construct spatial accessibility variables.

The openness, download methods, completeness of geographic coordinates and approval requirements of official facility data in sub-Saharan African countries are not completely consistent. On the one hand, this study focuses on spatial accessibility, and assessing the quality of health facilities, such as staffing and equipment, is beyond the scope of the study. On the other hand, OpenStreetMap data have been used in reproducible healthcare-accessibility research (Pérez 2026). Therefore, OSM data are used to represent spatial patterns in this study.

OSM data were processed in QGIS to construct two cluster-level spatial accessibility variables: distance to the nearest healthcare facility and distance to the nearest major road. Since the original OSM data contain many facility and road types that are not directly relevant to this study, the data were filtered, reprojected, calculated, joined, and megered.

For healthcare facilities, the raw OSM point layer was filtered using the amenity field. Only points classified as hospital or clinic were retained and exported as a separate healthcare facility layer. Pharmacies, dental clinics, veterinary clinics and other facility types were excluded because they are less relevant to delivery care.

For roads, the raw OSM road layer was filtered using the highway field. This study retained trunk, primary, secondary and their corresponding link types. The original road layers contained millions of features, including residential roads, service roads, paths and other local roads. Including all roads would make the nearest-road variable mainly capture proximity to any small road, rather than connection to the main transport network. After filtering, only about 1% of the original road features were retained, but these retained features better represent major road access for this study.

Then the DHS cluster layer, the filtered healthcare facility layer and the filtered major road layer were reprojected to a projected coordinate system suitable for each country. Because the original coordinates were stored in degrees, which are not appropriate for direct distance measurement in metres or kilometres. After reprojection, all relevant layers used the same coordinate system, allowing QGIS to calculate distances in metres, which were then converted into kilometres.

This study used the nearest-neighbour distance calculation tool in QGIS to spatially match DHS cluster points with the filtered OSM healthcare facility point layer and the major road layer, respectively, and DHS cluster points were used as the input layer. For the healthcare facility distance, the filtered hospital and clinic points were used as the target layer. QGIS identified the nearest healthcare facility point for each survey cluster and calculated the straight-line distance between them. For the road distance, the filtered major road line layer was used as the target layer. QGIS identified the nearest major road segment for each survey cluster and calculated the shortest straight-line distance from the cluster point to that road segment.

Then the two spatial variables were written into the attribute table of the DHS cluster layer. The attribute table containing the DHS cluster identifier and the spatial distance variables was then exported from QGIS and merged with the DHS KR individual data in Stata using the DHS cluster identifier, allowing each woman and child record to be linked to the spatial accessibility measures of its survey cluster.

Sample selection starts from the KR child records after the four countries are combined. The combined basic data include 56,592 child records. Considering that this study focuses on recent place of delivery and early breastfeeding, and that this information depends on maternal recall, this study first restricts the analysis sample to children born within 24 months before the survey. This can reduce recall error that may come from earlier birth records, and make the samples of the four countries all focus on relatively recent delivery experiences. This step removes 32,604 earlier birth records and retains 23,988 observations. Subsequently, the sample further requires that the key variables needed for RQ1 and RQ2 are all non-missing, including timely initiation of breastfeeding, place of delivery, caesarean section, main control variables and spatial accessibility variables. After completing these restrictions, the final analysis sample is marked as final_sample_main = 1, and is used for all main models of RQ1 and RQ2, with a total of 21,684 observations. In terms of sample size, Nigeria had the largest sample with 10,109 observations, followed by Tanzania with 4,219, Ghana with 3,828, and Zambia with 3,528. In Tanzania, several education and region categories perfectly predict facility delivery, so 366 observations are excluded from the adjusted RQ1 models, reducing the effective sample from 4,219 to 3,853.

5.2 Variables

5.2.1 Dependent Variable for RQ1: Institutional Delivery

The dependent variable for RQ1 is facility_delivery, indicating whether the woman delivered in a health facility. This variable is reconstructed based on the place of delivery variable m15 in the DHS Kids Recode (Croft et al. 2023). If the delivery occurred in a public or non-public health facility, it is coded as 1; if it occurred at home or in a non-health facility, it is coded as 0. This study uses this variable as a binary dependent variable to analyse whether spatial accessibility is associated with the use of institutional delivery services.

5.2.2 Dependent Variable for RQ2: Timely Initiation of Breastfeeding

The dependent variable for RQ2 is early_init_1h, indicating timely initiation of breastfeeding. It is constructed from the DHS variable on how long after birth breastfeeding was initiated (Croft et al. 2023). In the main definition, immediate breastfeeding after birth or breastfeeding initiated within one hour is coded as 1, while breastfeeding initiated later than one hour or not initiated is coded as 0 (World Health Organization and UNICEF 2021). This variable is used to examine whether place of delivery and caesarean section are associated with early newborn care practices after birth.

5.2.3 Explanatory Variables for RQ1: Spatial Accessibility

The explanatory variables for RQ1 measure spatial accessibility around respondents' residential locations, mainly based on two OSM-derived straight-line distance measures (dist_health_km, distance to the nearest health facility and dist_road_km, distance to the nearest major road). These variables were constructed in QGIS and transformed into several forms to examine whether spatial accessibility is associated with institutional delivery (Guagliardo 2004; Higgs 2004).

The first main specification uses log distance variables, ln_hdist and ln_rdist, constructed as ln(distance+1). Adding 1 allows clusters with zero or very short distances to be included before the log transformation, while keeping the original ordering of distances. The log form is used because the relationship between distance and service use may be non-linear: an increase from 1 km to 5 km may matter more for delivery choice than an increase from 30 km to 35 km. This study expects longer distance to health facilities and major roads to be associated with a lower likelihood of institutional delivery (Gabrysch and Campbell 2009; Tegegne et al. 2018).

The second specification uses binary accessibility variables. near_health5 indicates whether a DHS cluster is within 5 km of a health facility. This threshold is used to capture close facility availability to a point-based healthcare service locations (Guagliardo 2004; Tegegne et al. 2018). near_road10 indicates whether a DHS cluster is within 10 km of a major road. The road threshold is broader because major roads are line-based transport corridors and are used here to reflect connection to main transport network, rather than proximity to “any nearby road” such as local village roads, service roads or small paths. This study expects both near_health5 and near_road10 to be associated with a higher likelihood of institutional delivery.

The third specification uses the combined accessibility type variable typ_h10_r10 to compare whether health facility distance and road connection jointly define spatial accessibility conditions. It combines health facility access and major road access using the same 10 km threshold and divides clusters into four categories: near health + near road, near health + far road, far health + near road, and far health + far road. The reference group is near health + near road, especially focusing whether being far from both health facilities and major roads is associated with lower institutional delivery.

The fourth specification uses distance zones to compare different distance ranges. Health facility distance is grouped into within 5 km, 5–10 km and more than 10 km, while road distance is grouped into within 2 km, 2–10 km and more than 10 km. These variables are used to examine whether the association varies across distance ranges rather than depending only on a single cut-off (Tegegne et al. 2018).

The fifth specification uses the DHS Geospatial Covariates travel-time indicator, gc_travel10. This variable measures travel time from the cluster location to a high-density urban centre, rescaled in 10-unit increments. It is used as an additional geographical accessibility indicator to examine whether the spatial accessibility results have a consistent direction beyond the OSM-based facility and road distance variables (Weiss et al. 2018).

5.2.4 Explanatory Variables for RQ2: Place of Delivery and Caesarean Section

The core explanatory variable for RQ2 is facility_delivery, namely whether the delivery was institutional delivery, which is used to examine whether institutional delivery is associated with a higher likelihood of EIBF. This study expects that institutional delivery is positively associated with EIBF (Appiah et al. 2021; Bergamaschi et al. 2019).

The second key variable is the binary variable csection, indicating whether the delivery was by caesarean section. This variable comes from the DHS variable m17, with caesarean section coded as 1 and non-caesarean section coded as 0 (Croft et al. 2023). This study expects that caesarean section is negatively associated with EIBF (Yisma et al. 2019; Getaneh et al. 2021).

delivery_place3 is the three-category place of delivery variable. This variable divides place of delivery into home, public facility and non-public facility, with home as the reference group. This variable is used to further examine whether public and non-public facilities have different associations with EIBF compared with home delivery (Bergamaschi et al. 2019).

5.2.5 Additional Variables for Supplementary Analyse

Several additional variables are constructed for the supplementary RQ1 analyses. First, this study constructs a road-network distance variable to the nearest health facility, network_health_km, and its per-10-km version, network_health10. Unlike straight-line distance, network_health_km measures the shortest route from each cluster to the nearest health facility along the filtered road network. The calculation matches cluster points, health facility points and road segments in QGIS and includes tertiary-road links. Because the measure is sensitive to OSM road completeness and network matching and entails some sample loss, it is used only as a robustness check in Appendix Table A2, Panel D (Nesbitt et al. 2014).

Second, the raw health facility distance and road distance are converted into per-10-km variables as alternatives to the log distance variables. This specification keeps distance on its original linear scale and is used to check whether the main results are mainly driven by the log transformation.

Third, this study constructs an alternative combined accessibility type, typ_h10_r2, using health facility access within 10 km and major road access within 2 km. The 2 km road is closer to the Rural Access Index idea of being near a road that can be used throughout the year (World Bank 2016).

Fourth, threshold sensitivity checks are conducted using alternative health facility thresholds of 2.5, 5, 10, 15 and 20 km, and road thresholds of 2, 5, 10, 15 and 20 km. These checks are used to assess whether the results depend on one specific distance cut-off (Tegegne et al. 2018).

For RQ2, this study constructs early_init_1h_inclusive as a robustness variable. The main analysis uses the strict EIBF definition, where immediate initiation and initiation within the first hour are coded as timely initiation. The inclusive definition also treats "exactly one hour" as timely initiation. This is useful because breastfeeding initiation time is reported by mothers and may be affected by rounding or heaping around common time points such as one hour (World Health Organization and UNICEF 2021). The inclusive definition is therefore used to check whether the RQ2 results are sensitive to this boundary. The main focus is whether the association between place of delivery, caesarean section and EIBF remains consistent when the timing boundary is treated more broadly.

5.2.6 Control Variables

This study uses the same group of control variables in the main models of RQ1 and RQ2, including child characteristics, maternal characteristics, household socioeconomic status, place of residence, region and antenatal care. These variables mainly come from DHS original individual and birth history data, and some are regrouped according to the needs of the analysis. The choice of control variables is based on three considerations (Croft et al. 2023). First, maternal and newborn health practices are usually influenced by factors such as maternal age, education, marital status, reproductive experience and antenatal care, and therefore maternal characteristics and contact with maternity services need to be controlled. Second, household wealth, urban-rural residence and region reflect socioeconomic conditions, service accessibility and the health system environment, and may affect both institutional delivery and EIBF. Third, child sex, multiple birth and birth order may be related to delivery risk, care needs and household reproductive experience, and may also affect whether women choose institutional delivery and postnatal care practices (Gabrysch and Campbell 2009; Moyer and Mustafa 2013; Appiah et al. 2021).

Child-level variables include child_female and non_singleton. child_female indicates whether the child is a girl, with girls coded as 1 and boys coded as 0. Child sex should usually not have a direct strong mechanism relationship with place of delivery or breastfeeding, but in some social contexts it may be related to care behavior or household preferences, and therefore is included as a basic control variable (Appiah et al. 2021). non_singleton indicates whether the child is not a singleton. Multiple pregnancy often has higher obstetric risk, is more likely to involve institutional delivery or caesarean section, and may also affect breastfeeding initiation after birth, so it needs to be controlled.

The maternal age variable is mother_age_birth_cat4, indicating maternal age groups at birth. This study uses four groups: 15–19 years, 20–24 years, 25–34 years and 35–49 years. Women in different age groups may differ in reproductive risks, delivery experience, family support and health service utilization. The 15–19 group represents adolescent mothers, who may face higher social and physiological risks; the 20–24 and 25–34 groups represent the main reproductive age groups; and the 35–49 group represents older maternal age, which may have different risk conditions and service needs. Therefore, controlling age groups helps to reduce the influence of different reproductive age structures on institutional delivery and EIBF (Gabrysch and Campbell 2009; Appiah et al. 2021).

The birth order variable is birth_order4, indicating the child's birth order groups. It is treated as a categorical variable, with four categories: first birth, second birth, third birth, and fourth or higher birth order. Birth order affects mothers' reproductive experience and delivery risk, and may also affect household attitudes towards institutional delivery and breastfeeding. For example, first-time mothers may be more inclined to seek institutional services and may also rely more on guidance from healthcare workers; high-parity mothers may have more delivery and breastfeeding experience, but may also choose different places of delivery because of previous experience. Therefore, this study uses birth order as a control variable (Alzaheb 2017; Appiah et al. 2021).

Marital/cohabitation status is simplified from the original DHS marital variable v501 to a binary variable marital_union: 1 for currently married or cohabiting individuals, and 0 for other statuses (Croft et al. 2023). This focuses on whether a woman is in a current partnership, as this is generally more directly related to reproductive support, family resources, and the environment for childbirth decisions (Moyer and Mustafa 2013).

Education level (v106), wealth level (v190), urban/rural residence (v025), and region (v024) are all directly derived from the original DHS variables and are categorical variables (Croft et al. 2023). They represent the mother's human capital, family economic status, living environment, and regional institutional/service background at a larger scale, respectively, and are the most common and necessary socioeconomic control factors explaining differences in childbirth and feeding behavior (Gabrysch and Campbell 2009; Moyer and Mustafa 2013; Appiah et al. 2021).

The number of antenatal care (ANC) visits was regrouped from the original DHS variable m14 into a categorical variable, anc_cat, divided into 0 visits, 1–3 visits, 4–7 visits, and 8 visits or more (Croft et al. 2023). Different frequency ranges were used to distinguish women who did not receive ANC, received fewer ANC visits, and received relatively sufficient ANC visits. Antenatal care reflects women's contact with the healthcare system before delivery, their tendency to use health services, health education, and birth preparedness, and may influence their subsequent choice of place of delivery and postnatal care practices (Gabrysch and Campbell 2009; Moyer and Mustafa 2013). However, in RQ1, ANC may also be influenced by spatial accessibility variables. For example, women living farther from healthcare facilities or major roads may face longer travel time, higher transport costs and greater mobility barriers, and therefore may be less likely to receive or continuously complete ANC visits; ANC may then further increase the likelihood of facility delivery. Therefore, ANC may partly lie on the pathway of "spatial accessibility → antenatal care → facility delivery". For this reason, this study controls for ANC in the main models, and also compares models without and with ANC in the sensitivity check to test whether the RQ1 results are sensitive to this variable. Therefore, the spatial accessibility coefficients in the main models of RQ1 are interpreted as conditional associations after controlling for prior antenatal service contact.

5.3 Descriptive Statistics

Figures 1–4 show that health facilities are spatially uneven across the four countries, while major roads provide broader transport corridors but do not cover all survey areas equally, especially in more peripheral regions. Table 1 reports the descriptive statistics of the final analysis samples from the four countries. The four countries show clear differences in the level of institutional delivery. Zambia has the highest proportion of institutional delivery, at 93.7%; Ghana and Tanzania are also at relatively high levels, at 86.8% and 83.2%, respectively; by contrast, Nigeria has a much lower proportion of institutional delivery, at only 41.7%. This indicates that there are large differences across the four countries in women's access to facility-based delivery. In terms of delivery facility type, public facility delivery accounts for the main part in all four countries, especially in Zambia and Ghana, with proportions of 89.2% and 76.4%, respectively. Nigeria has a lower proportion of public facility delivery, at 26.9%, while the proportion of non-public facility delivery is 14.8%.

The proportion of caesarean section also differs across the four countries. Ghana has the highest caesarean section proportion, at 19.7%; Zambia and Tanzania are 11.1% and 10.4%, respectively; and Nigeria is the lowest, at 5.2%. Since caesarean section usually occurs inside health facilities and may affect early mother–infant contact and breastfeeding initiation after birth, it is included in the model as an important variable in RQ2. The proportion of timely initiation of breastfeeding also shows country differences. Under the strict EIBF definition, Tanzania and Zambia have higher proportions, at 75.0% and 70.4%, respectively; Ghana is 60.1%; and Nigeria is the lowest, at 36.8%.

The spatial accessibility indicators show that the four countries also have clear differences in proximity to health facilities and connection to major roads. The proportion with access to health facilities within 5 km is highest in Zambia, at 45.2%; Ghana is 34.4%; Tanzania is 29.8%; and Nigeria is the lowest, at 24.1%. In terms of average distance to health facilities, Nigeria has the longest average distance, at 21.29 km; Tanzania is 18.20 km; and Zambia and Ghana are 14.22 km and 13.87 km, respectively. By contrast, the proportion with access to major roads within 10 km is much higher overall: Nigeria and Ghana are 89.5% and 88.9%, respectively; Tanzania is 80.8%; and Zambia is the lowest, but still reaches 62.1%. The average distance to major roads is also clearly shorter than the average distance to health facilities. Nigeria, Ghana and Tanzania are 3.85 km, 4.08 km and 5.40 km, respectively; Zambia is the highest, at 13.39 km.

This difference in distribution suggests that distance to health facilities and distance to roads measure two different types of spatial resources. Health facilities are point-based service resources, and their spatial distribution is relatively sparse. Major roads are linear transport networks, and even though this study only retains higher-level roads such as trunk, primary, secondary and their link types, their spatial coverage is still usually larger than that of health facility points. At the same time, the high proportion of access to major roads within 10 km also suggests that this binary variable may have limited discriminatory power in Nigeria, Ghana and Tanzania. Therefore, in addition to the binary road variable, the following RQ1 analysis will combine continuous road distance, road distance groups, combined accessibility types and threshold sensitivity checks to interpret the relationship between road accessibility and institutional delivery.

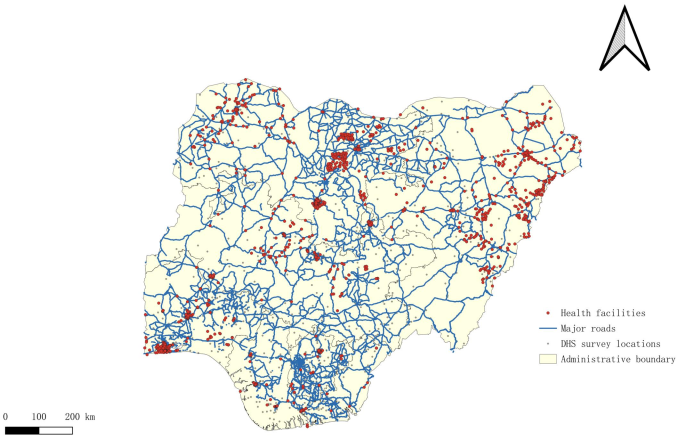
The combined accessibility indicator further shows that Zambia has the highest proportion of being far from both health facilities and major roads, at 21.4%; Tanzania is 15.9%; and Ghana and Nigeria are relatively lower, at 10.4% and 9.2%, respectively. This indicates that although Zambia has a very high proportion of institutional delivery, its road accessibility and combined spatial accessibility conditions are relatively weaker. In contrast, Nigeria has better major road connection indicators, but lower proximity to health facilities and a lower proportion of institutional delivery. Overall, the descriptive statistics show that the four countries have clear differences in institutional delivery, EIBF levels, caesarean section proportion and spatial accessibility. Therefore, estimating models separately at the country level can more clearly present the relationship patterns within each country, and avoid using one overall average relationship to mask cross-country differences in service coverage and spatial structure.

Table 1 Descriptive statistics for the final analytical sample

Variable	Nigeria	Ghana	Tanzania	Zambia
Unweighted N	10109	3828	4219	3528
Facility delivery (%)	41.7	86.8	83.2	93.7

EIBF, strict definition (%)	36.8	60.1	75	70.4
C-section (%)	5.2	19.7	10.4	11.1
Public facility delivery (%)	26.9	76.4	76.4	89.2
Non-public facility delivery (%)	14.8	10.5	6.8	4.5
Rural residence (%)	62.6	53.1	72.3	60.2
Health facility within 5 km (%)	24.1	34.4	29.8	45.2
Major road within 10 km (%)	89.5	88.9	80.8	62.1
Far from both health facility and major road, H10/R10 (%)	9.2	10.4	15.9	21.4
Distance to nearest health facility, mean km	21.29	13.87	18.2	14.22
Distance to nearest major road, mean km	3.85	4.08	5.4	13.39
Log health distance, mean	2.62	2.26	2.39	2.12
Log road distance, mean	1.17	1.24	1.37	1.88
Network distance to nearest health facility, mean km	37.9	27.96	31.36	27.26

Notes: N is unweighted. Percentages and means are weighted using probability weights. Continuous distance variables are reported as weighted means. The sample is restricted to final_sample_main = 1.



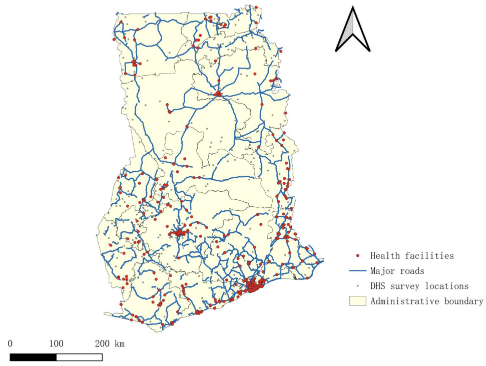
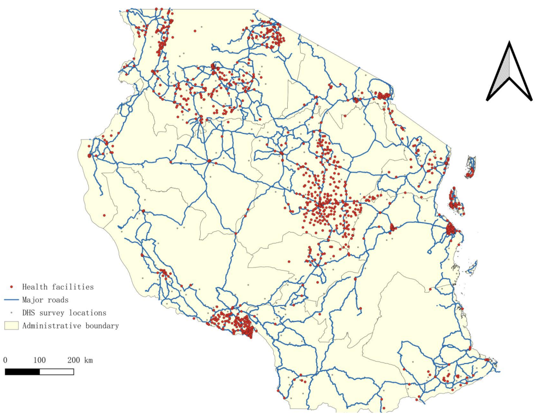


Figure 1 Spatial Data Distribution in Nigeria

Figure 2 Spatial Data Distribution in Ghana



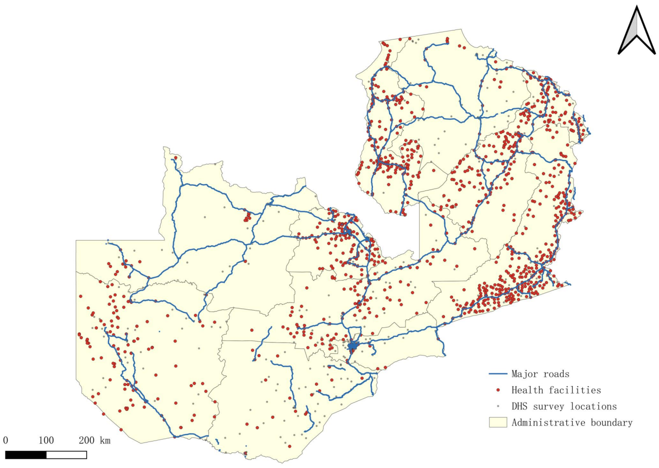


Figure 3 Spatial Data Distribution in Tanzania

Figure 4 Spatial Data Distribution in Zambia

6 Methods

The two research questions in this study correspond to two binary dependent variables. RQ1 focuses on the relationship between spatial accessibility and institutional delivery, with the dependent variable being facility_delivery, namely whether the delivery occurred in a health facility. RQ2 focuses on the relationship between place of delivery and timely initiation of breastfeeding, with the dependent variable being early_init_1h, namely whether the child initiated breastfeeding within one hour after birth. Since both dependent variables are binary variables, this study mainly uses logit models for estimation. The regression results are reported using both odds ratios (ORs) and average marginal effects (AMEs). ORs are used to present the proportional relationship between variables and the odds of the outcome occurring, while AMEs are used to explain changes in predicted probabilities corresponding to changes in variables, which is convenient for substantive interpretation. All models use DHS probability weights to improve the representativeness of the estimates for the survey population, and control for covariates such as child, maternal, socioeconomic, residence, region and antenatal care variables. Heterogeneity and robustness analyses are used to examine whether the main results remain consistent across different groups, different variable definitions and different model specifications.

6.1 RQ1 model

RQ1 examines whether spatial accessibility is associated with institutional delivery. The basic model is written as:

$$\log\left(\frac{P(\text{Facility}_i=1)}{1-P(\text{Facility}_i=1)}\right)=\alpha+\beta A_i+X_i'\gamma+\delta_r+\varepsilon_i$$

Facilityi indicates whether individual i delivered in a health facility, Ai indicates the spatial accessibility variable, Xi indicates individual- and household-level control variables, and region fixed effects indicates regional fixed effects. The model is estimated separately in the four countries.

For the log distance model, the formula is written as:

$$\log\left(\frac{P(\text{Facility}_i=1)}{1-P(\text{Facility}_i=1)}\right)=\alpha+\beta_1\ln(\text{dist\_health\_km}_i+1)+\beta_2\ln(\text{dist\_road\_km}_i+1)+X_i'\gamma+\delta_r+\varepsilon_i$$

ln_hdisti indicates the log value of distance to the nearest health facility, and ln_rdisti indicates the log value of distance to the nearest major road. If b1 or b2 is below 0, it means that the farther the distance, the lower the likelihood of institutional delivery.

For the binary accessibility model, the formula is written as:

$$\log\left(\frac{P(\text{Facility}_i=1)}{1-P(\text{Facility}_i=1)}\right)=\alpha+\beta_1\text{Health5}_i+\beta_2\text{Road10}_i+X_i'\gamma+\delta_r+\varepsilon_i$$

near_health5i indicates whether the cluster is located within 5 km of a health facility, and near_road10i indicates whether the cluster is located within 10 km of a major road.

For the combined accessibility model, this study divides clusters into four categories:

$$\text{HealthNear}_i=\begin{cases}1, & \text{dist\_health\_km}_i\leq 10,\\ 0, & \text{dist\_health\_km}_i>10.\end{cases}$$

$$\text{RoadNear}_i=\begin{cases}1, & \text{dist\_road\_km}_i\leq 10,\\ 0, & \text{dist\_road\_km}_i>10.\end{cases}$$

$$\text{Typology}_i=\begin{cases}1, & \text{HealthNear}_i=1,\ \text{RoadNear}_i=1,\text{near health + near road}\\ 2, & \text{HealthNear}_i=1,\ \text{RoadNear}_i=0,\ \text{near health + far road}\\ 3, & \text{HealthNear}_i=0,\ \text{RoadNear}_i=1,\ \text{far health + near road}\\ 4, & \text{HealthNear}_i=0,\ \text{RoadNear}_i=0.\ \text{far health + far road}\end{cases}$$

The formula is written as:

$$\log\left(\frac{P(\text{Facility}_i=1)}{1-P(\text{Facility}_i=1)}\right)=\alpha+\beta_1\text{Typology}_{2i}+\beta_2\text{Typology}_{3i}+\beta_3\text{Typology}_{4i}+X_i'\gamma+\delta_r+\varepsilon_i$$

This model is used to examine whether areas far from both health facilities and major roads have cumulative spatial disadvantage

6.2 RQ2 model

The basic model is written as:

$$\log\left(\frac{P(\text{EIBF}_i=1)}{1-P(\text{EIBF}_i=1)}\right)=\alpha+\beta\text{Facility}_i+X_i'\gamma+\delta_r+\varepsilon_i$$

EIBFi indicates whether the child initiated breastfeeding within one hour after birth, Facilityi indicates whether the delivery was institutional delivery, and Xi and region fixed effects have the same meanings as in RQ1.

To consider the effect of caesarean section, this study further adds the variable Csectioni:

$$\log\left(\frac{P(\text{EIBF}_i=1)}{1-P(\text{EIBF}_i=1)}\right)=\alpha+\beta\text{Facility}_i+\theta\text{Csection}_i+X_i'\gamma+\delta_r+\varepsilon_i$$

Csectioni indicates whether the delivery was by caesarean section.

To further distinguish facility types, this study divides place of delivery into home, public facility and non-public facility, with home as the reference group.

$$\log\left(\frac{P(EIBF_i=1)}{1-P(EIBF_i=1)}\right)=\alpha+\beta_1 PublicFacility_i+\beta_2 NonPublicFacility_i+\theta Csection_i+X_i'\gamma+\delta_r+\varepsilon_i$$

Publici indicates delivery in a public facility, and Nonpublici indicates delivery in a non-public facility.

Average marginal effects, AME is written as:

$$AME=\frac{1}{N}\sum_{i=1}^{N}\left[\hat{P}(Y_i=1 \mid D_i=1,X_i)-\hat{P}(Y_i=1 \mid D_i=0,X_i)\right]$$

7 Results

7.1 RQ1: Spatial Accessibility and Institutional Delivery

Table 2-5 report the odds ratios from the RQ1 logit models for each country, while Table 6 reports predicted probabilities for the four spatial accessibility typologies.

The analysis compares two main dimensions of spatial accessibility: proximity to healthcare service points and connection to the main transport network. All models control for child characteristics, maternal characteristics, socioeconomic status, urban-rural residence, region, antenatal care and other variables. Overall, the results show that spatial accessibility is associated with institutional delivery, but the main accessibility dimension differs across countries.

In Nigeria, the relationship between institutional delivery and proximity to health facilities is the clearest. The farther the distance to the nearest health facility, the lower the likelihood of institutional delivery; in the adjusted model, the OR of log health distance is 0.902, and it reaches statistical significance ($p < 0.01$). The binary-accessibility model points in the same direction: having a health facility within 5 km is positively associated with institutional delivery (OR = 1.423, $p < 0.01$). In contrast, road distance and whether there is a major road within 10 km are not statistically significant in Nigeria. This suggests that in Nigeria, whether health facilities themselves are spatially close to women is a more prominent geographical factor in differences in institutional delivery.

The results for Tanzania are more stable than those for Nigeria, and they also better reflect the dual structure of spatial accessibility. Both health facility distance and road distance are significantly associated with institutional delivery: the OR of log health distance is 0.776, and the OR of log road distance is 0.801, both reaching $p < 0.01$. In other words, areas farther from health facilities and major roads have lower odds of institutional delivery. The binary-accessibility results are consistent with this pattern: both health-facility access within 5 km and major-road access within 10 km are positively associated with institutional delivery and statistically significant. It can therefore be seen that in Tanzania, spatial differences in institutional delivery are constrained by both the distribution of healthcare service points and transport connection conditions.

The results for Ghana and Zambia highlight road accessibility more strongly. In Ghana, although both health facility distance and road distance are significantly negative in the continuous distance models, with ORs of 0.770 and 0.772 respectively (both $p < 0.01$), the road variable has stronger explanatory power in the more intuitive accessibility classification.

Living within 10 km of a major road is positively associated with institutional delivery (OR = 2.409, $p < 0.01$), whereas the estimate for having a health facility within 5 km is positive but not statistically significant. This shows that in Ghana, spatial differences in institutional delivery are not only about how close the nearest health facility is, but are more reflected in whether the community is close to the main transport network. In Zambia, health facility distance itself does not reach statistical significance, and having a health facility within 5 km also does not show a clear relationship. In contrast, living within 10 km of a major road is positively associated with institutional delivery (OR = 1.720, $p < 0.01$), and the distance-zone model shows the same general direction. Although the overall level of institutional delivery in Zambia is relatively high, areas with poorer road accessibility still show a relatively lower level of institutional delivery.

The combined variable further shows that more stable disadvantageous results usually appear in the pattern of being far from both health facilities and major roads. Ghana is the clearest case: the predicted probability for the "near health + near road" group is 0.897, while the "far health + far road" group decreases to 0.784, with a difference in the probability of institutional delivery of about 11.3 percentage points, and it reaches statistical significance ($p < 0.01$). Tanzania and Zambia also show the same direction, with predicted probabilities decreasing by about 6.0 percentage points ($p < 0.01$) and 3.3 percentage points ($p < 0.05$), respectively. The Nigerian results also show lower institutional delivery outside the most favourable accessibility type, but the decline does not form a clear progressive gradient. Combined with the continuous distance and 5 km facility accessibility results, the more stable evidence in Nigeria still comes from proximity to health facilities.

Finally, the DHS Geospatial Covariates travel-time models in Tables 2–5 provide supplementary evidence for the main results.In Nigeria, Ghana and Tanzania, travel time is negatively and significantly associated with institutional delivery, with odds ratios of 0.974, 0.955 and 0.971 respectively, indicating that areas with longer travel time have lower levels of institutional delivery. Ghana and Tanzania both reach $p < 0.01$, and Nigeria reaches $p < 0.05$. The result for travel time in Zambia is negative in direction but not significant, which is also consistent with the relatively weaker spatial gradient in the main analysis and the relatively high overall level of institutional delivery.

Appendix Table A1 reports heterogeneity by urban-rural residence and household wealth. The associations are generally clearer in rural samples in Ghana, Tanzania and Zambia, while Nigeria shows significant results in both urban and rural samples. Wealth-group patterns are less consistent across countries and do not indicate that the associations are concentrated in one wealth group.

Appendix Table A2 reports four robustness checks using an alternative accessibility typology, raw distances, an alternative standard-error specification and network health-facility distance. Although statistical significance varies across specifications and countries, the main coefficient directions are broadly consistent with the primary analysis.

Appendix Table A3 compares models without controls, with controls excluding ANC and with controls including ANC. Adding controls attenuates several unadjusted associations, while the additional inclusion of ANC produces relatively small changes in the direction of the main spatial-accessibility estimates. ANC is therefore retained in the main models, and the reported coefficients are interpreted as associations conditional on the included covariates.

Appendix Table A4 reports the weighted threshold distributions and sensitivity models for alternative health-facility and road cut-offs. The main directions persist under several alternative thresholds, although the relevant distance range differs across countries, particularly for road access.

In summary, the results of RQ1 show a statistical association between spatial accessibility and institutional delivery, but the dominant dimension differs across countries. Nigeria mainly reflects proximity to health facilities. Ghana and Zambia highlight road accessibility more strongly, indicating that connection to the main transport network captures important spatial differences in these two countries. Tanzania shows stable relationships in both dimensions of health facility distribution and road connection, and shows a more obvious decline in institutional delivery in areas with dual spatial disadvantage. Overall, spatial differences in institutional delivery should be interpreted in relation to both health facility layout and transport-network connection, but their relative importance depends on the national context.

Table 2 RQ1 main results: spatial accessibility and facility delivery, odds ratios - Nigeria

facility_delivery	(1) Log distances	(2) Availability	(3) Typology	(4) Distance zones	(5) Travel time
Log health distance, ln(km+1)	0.902***				
	(0.029)				
Log road distance, ln(km+1)	0.973				
	(0.042)				
Health facility within 5 km		1.423***			
		(0.119)			
Major road within 10 km		1.040			
		(0.109)			
Near health + far road			0.499*		
			(0.139)		
Far health + near road			0.765***		
			(0.058)		
Far health + far road			0.813*		
			(0.101)		
Health <=5 km vs >10 km					
				1.426***	
Health 5-10 km vs >10 km				(0.123)	
				1.011	
Road <=2 km vs >10 km				(0.100)	
				1.050	
Road 2-10 km vs >10 km				(0.120)	
				1.031	
DHS GC travel time, per 10 units				(0.114)	0.974**
					(0.011)
No. observations	10109	10109	10109	10109	10109
Pseudo R2	0.376	0.376	0.376	0.376	0.375

Notes: Odds ratios are reported. Standard errors in parentheses.
* p < 0.10, ** p < 0.05, *** p < 0.01.
All models use the same final analytical sample and probability weights.
All models control for child, maternal, socioeconomic, residence, regional and ANC variables.
Reference category for typology: near health + near road. Reference categories for distance zones: >10 km.

Table 3 RQ1 main results: spatial accessibility and facility delivery, odds ratios - Ghana

facility_delivery	(1) Log distances	(2) Availability	(3) Typology	(4) Distance zones	(5) Travel time
Log health distance, ln(km+1)	0.770***				
	(0.071)				
Log road distance, ln(km+1)	0.772***				
	(0.066)				
Health facility within 5 km		1.457			
		(0.340)			
Major road within 10 km		2.409***			
		(0.400)			
Near health + far road			0.784		
			(0.354)		
Far health + near road			0.758		
			(0.137)		
Far health + far road			0.317***		
			(0.070)		
Health <=5 km vs >10 km				1.539*	
				(0.345)	
Health 5-10 km vs >10 km				1.225	
				(0.297)	
Road <=2 km vs >10 km				2.354***	
				(0.462)	
Road 2-10 km vs >10 km				2.308***	
				(0.422)	
DHS GC travel time, per 10 units					0.955***
					(0.011)
No. observations	3828	3828	3828	3828	3828
Pseudo R2	0.286	0.290	0.290	0.290	0.282

Notes: Odds ratios are reported. Standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
All models use the same final analytical sample and probability weights.
All models control for child, maternal, socioeconomic, residence, regional and ANC variables.
Reference category for typology: near health + near road. Reference categories for distance zones: >10 km.

Table 4 RQ1 main results: spatial accessibility and facility delivery, odds ratios - Tanzania

facility_delivery	(1) Log distances	(2) Availability	(3) Typology	(4) Distance zones	(5) Travel time
Log health distance, ln(km+1)	0.776***				
	(0.062)				
Log road distance, ln(km+1)	0.801***				
	(0.052)				
Health facility within 5 km		1.664***			
		(0.325)			
Major road within 10 km		1.393***			
		(0.174)			
Near health + far road			0.885		
			(0.245)		
Far health + near road			0.887		
			(0.129)		
Far health + far road			0.624***		
			(0.106)		
Health <=5 km vs >10 km				1.592**	
				(0.325)	
Health 5-10 km vs >10 km				0.965	
				(0.146)	
Road <=2 km vs >10 km				1.618***	
				(0.258)	
Road 2-10 km vs >10 km				1.315**	
				(0.180)	
DHS GC travel time, per 10 units					0.971***
					(0.008)
No. observations	3853	3853	3853	3853	3853
Pseudo R2	0.211	0.206	0.204	0.207	0.206

Notes: Odds ratios are reported. Standard errors in parentheses.
* p < 0.10, ** p < 0.05, *** p < 0.01.
All models use probability weights. In Tanzania, 366 observations are excluded from the adjusted models because of perfect prediction.
All models control for child, maternal, socioeconomic, residence, regional and ANC variables.
Reference category for typology: near health + near road. Reference categories for distance zones: >10 km.

Table 5 RQ1 main results: spatial accessibility and facility delivery, odds ratios - Zambia

facility_delivery	(1) Log distances	(2) Availability	(3) Typology	(4) Distance zones	(5) Travel time
Log health distance, ln(km+1)	0.854 (0.091)				
Log road distance, ln(km+1)	0.859* (0.067)				
Health facility within 5 km		1.088 (0.258)			
Major road within 10 km		1.720*** (0.325)			
Near health + far road			0.815 (0.220)		
Far health + near road			1.167 (0.312)		
Far health + far road			0.546** (0.140)		
Health <=5 km vs >10 km				1.174 (0.289)	
Health 5-10 km vs >10 km				1.188 (0.283)	
Road <=2 km vs >10 km				1.595* (0.403)	
Road 2-10 km vs >10 km				1.784** (0.404)	
DHS GC travel time, per 10 units					0.994 (0.007)
No. observations	3528	3528	3528	3528	3528
Pseudo R2	0.203	0.204	0.206	0.204	0.199

Notes: Odds ratios are reported. Standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
All models use the same final analytical sample and probability weights.
All models control for child, maternal, socioeconomic, residence, regional and ANC variables.
Reference category for typology: near health + near road. Reference categories for distance zones: >10 km.

Table 6 RQ1 predicted probabilities by spatial accessibility typology

Accessibility typology	Nigeria	Ghana	Tanzania	Zambia
Near health + near road	0.441	0.897	0.833	0.948
	(0.008)	(0.010)	(0.013)	(0.008)
Near health + far road	0.348	0.878	0.818	0.939
	(0.035)	(0.036)	(0.032)	(0.010)
Far health + near road	0.404	0.875	0.819	0.955
	(0.006)	(0.009)	(0.011)	(0.008)
Far health + far road	0.412	0.784	0.773	0.915
	(0.014)	(0.020)	(0.017)	(0.010)

Notes: Predicted probabilities are reported. Standard errors in parentheses.
The typology uses health facility distance of 10 km and major road distance of 10 km.
All models use the same final analytical sample and probability weights, with the same controls as the main RQ1 models.

7.2 RQ2: Place of Delivery, Caesarean Section and Timely Initiation of Breastfeeding

Tables 7–10 report the logit regression results for the relationship between place of delivery, caesarean section and timely initiation of breastfeeding, while Tables 11–14 report the corresponding average marginal effects. All models control for child characteristics, maternal characteristics, socioeconomic status, residence and other variables. Overall, the results of RQ2 are relatively stable: in the four countries, institutional delivery is significantly associated with a higher likelihood of timely initiation of breastfeeding, while caesarean section is significantly associated with a lower likelihood of timely initiation of breastfeeding.

First, the baseline model in Table 7-10 shows that institutional delivery is significantly positively associated with EIBF in all four countries. The odds ratios for Nigeria, Ghana, Tanzania and Zambia are 1.248, 1.704, 2.113 and 1.693, respectively, all reaching $p < 0.01$. The corresponding average marginal effects in Tables 11–14 show that institutional delivery is associated with increases in the probability of EIBF of about 5.0, 12.4, 14.1 and 11.5 percentage points, respectively. This means that in all four countries, women who deliver in institutions have a higher likelihood of timely initiation of breastfeeding than women who deliver outside institutions.

The core models in Tables 7–10 show that after adding the caesarean section variable, the positive relationship between institutional delivery and EIBF remains statistically significant at $p < 0.01$ in all four countries. Specifically, after controlling for caesarean section and other covariates, the odds ratios of institutional delivery are 1.358 for Nigeria, 2.183 for Ghana, 2.552 for Tanzania and 2.035 for Zambia. The corresponding average marginal effects in Tables 11–14 are increases of about 6.8, 16.9, 16.2 and 14.4 percentage points, respectively. Compared with the model without controlling for caesarean section, the odds ratios of institutional delivery increase in all four countries after adding caesarean section. This indicates that the positive relationship between institutional delivery and EIBF becomes clearer after adjusting for caesarean section as a delivery process factor.

At the same time, caesarean section shows a very strong and stable negative association with EIBF. In all countries, the odds ratios of caesarean section are significantly below 1, and the values are very small. In the models including caesarean section, the odds ratios of caesarean section in Nigeria, Ghana, Tanzania and Zambia are 0.303, 0.215, 0.114 and 0.138, respectively, all reaching $p < 0.01$. The average marginal effects in Tables 11–14 show that caesarean section is associated with decreases in the probability of EIBF of about 21.5, 34.8, 44.2 and 44.0 percentage points, respectively. That is to say, women who receive caesarean section have a much lower likelihood of timely breastfeeding than women with vaginal delivery. In the sample limited to institutional delivery, caesarean section is still significantly associated with a lower likelihood of EIBF. After excluding caesarean deliveries, the positive relationship between institutional delivery and EIBF still exists. The above results show that because caesarean section mainly occurs in health facilities, but is itself significantly negatively associated with EIBF, the EIBF advantage of the institutional delivery group will be underestimated if caesarean and non-caesarean deliveries are not distinguished.

The delivery-place-type models in Tables 7–10 further distinguish institutional delivery into public and non-public facilities. This model also controls for caesarean section and other covariates, and can examine whether the positive relationship of institutional delivery is driven only by a certain type of facility. With home delivery as the reference group, public facility delivery shows a significant positive relationship in all four countries, with odds ratios of 1.394 for Nigeria, 2.161 for Ghana, 2.629 for Tanzania and 2.056 for Zambia, all reaching $p < 0.01$; the corresponding average marginal effects are 7.4, 16.7, 16.6 and 14.6 percentage points, respectively. The direction of non-public facility delivery is also positive: the odds ratios for Nigeria, Ghana and Tanzania are 1.235, 2.754 and 1.727, respectively, and reach statistical significance; the odds ratio for Zambia is 1.561, reaching marginal significance. The average marginal effects also show that non-public facility delivery corresponds to a higher probability of EIBF in all four countries, with a magnitude of about 4.6–21.5 percentage points. It can therefore be seen that both public and non-public facilities are generally associated with a higher likelihood of EIBF, which further supports the importance of institutional delivery.

Appendix Table A5 reports the sensitivity analysis using the inclusive EIBF definition, which also classifies initiation reported as exactly one hour after birth as timely. Appendix Table A7 shows that the weighted EIBF proportion increases in all four countries under this definition. In the facility-delivery-only model, the positive association remains statistically significant in Ghana, Tanzania and Zambia, but not in Nigeria. After caesarean section is included, facility delivery is positively associated with EIBF in all four countries, while caesarean section is negatively associated with EIBF. The main interpretation is therefore broadly robust, although the initial Nigeria estimate is sensitive to model specification.

Appendix Table A6 reports subgroup-specific AMEs and interaction tests for maternal age, birth order, household wealth, residence and education. At the 5% level, the interaction tests indicate differences by birth order in Nigeria, household wealth in Tanzania and maternal education in Ghana. Weaker evidence at the 10% level is found for maternal age in Nigeria and Tanzania and for birth order in Tanzania. There is no statistically significant urban–rural interaction in any of the four countries. Overall, the subgroup variation is country-specific rather than showing a common pattern across the four countries.

Overall, the results of RQ2 show that there is a stable relationship between place of delivery and timely initiation of breastfeeding. In all four countries, institutional delivery is associated with a higher likelihood of EIBF. After adding the caesarean section variable, the odds ratios of institutional delivery increase in all four countries. This indicates that the advantage of institutional delivery in the overall sample may be partly underestimated by caesarean section: caesarean section mainly occurs within health facilities, but it is itself significantly negatively associated with EIBF, and therefore lowers the overall EIBF level of the institutional delivery group. After controlling for or excluding caesarean section, the positive association between institutional delivery and EIBF becomes more pronounced.

Table 7 RQ2 main results: place of delivery, c-section and EIBF, odds ratios - Nigeria

	(1) Facility	(2) + C-section	(3) Place type	(4) Facility births	(5) Vaginal births
early_init_1h					
Facility delivery	1.248***	1.358***			1.362***
	(0.082)	(0.090)			(0.091)
Public facility vs home			1.394***		
			(0.096)		
Non-public facility vs home			1.235**		
			(0.112)		
C-section		0.303***	0.306***	0.312***	
		(0.040)	(0.041)	(0.042)	
No. observations	10109	10109	10109	4499	9568
Pseudo R2	0.038	0.047	0.048	0.054	0.045

Notes: Odds ratios are reported. Standard errors are in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
All models use the same final analytical sample and probability weights.
All models control for child, maternal, socioeconomic, residence, regional and ANC variables.
Model 'Facility births' is restricted to facility deliveries. Model 'Vaginal births' excludes c-section births.

Table 8 RQ2 main results: place of delivery, c-section and EIBF, odds ratios - Ghana

	(1) Facility	(2) + C-section	(3) Place type	(4) Facility births	(5) Vaginal births
early_init_1h					
Facility delivery	1.704***	2.183***			2.168***
	(0.235)	(0.311)			(0.316)
Public facility vs home			2.161***		
			(0.308)		
Non-public facility vs home			2.754***		
			(0.616)		
C-section		0.215***	0.211***	0.210***	
		(0.027)	(0.026)	(0.026)	
No. observations	3828	3828	3828	3281	3158
Pseudo R2	0.041	0.096	0.097	0.107	0.048

Notes: Odds ratios are reported. Standard errors are in parentheses.
* p < 0.10, ** p < 0.05, *** p < 0.01.
All models use the same final analytical sample and probability weights.
All models control for child, maternal, socioeconomic, residence, regional and ANC variables.
Model 'Facility births' is restricted to facility deliveries. Model 'Vaginal births' excludes c-section births.

Table 9 RQ2 main results: place of delivery, c-section and EIBF, odds ratios - Tanzania

	(1) Facility	(2) + C-section	(3) Place type	(4) Facility births	(5) Vaginal births
early_init_1h					
Facility delivery	2.113***	2.552***			2.618***
	(0.261)	(0.319)			(0.335)
Public facility vs home			2.629***		
			(0.330)		
Non-public facility vs home			1.727***		
			(0.364)		
C-section		0.114***	0.117***	0.116***	
		(0.017)	(0.017)	(0.017)	
No. observations	4219	4219	4219	3502	3763
Pseudo R2	0.072	0.143	0.145	0.164	0.082

Notes: Odds ratios are reported. Standard errors are in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
All models use the same final analytical sample and probability weights.
All models control for child, maternal, socioeconomic, residence, regional and ANC variables.
Model 'Facility births' is restricted to facility deliveries. Model 'Vaginal births' excludes c-section births.

Table 10 RQ2 main results: place of delivery, c-section and EIBF, odds ratios - Zambia

	(1) Facility	(2) + C-section	(3) Place type	(4) Facility births	(5) Vaginal births
early_init_1h					
Facility delivery	1.693^{***}	2.035^{***}			2.022^{***}
	(0.282)	(0.343)			(0.340)
Public facility vs home			2.056^{***}		
			(0.347)		
Non-public facility vs home			1.561^{*}		
			(0.398)		
C-section		0.138^{***}	0.139^{***}	0.134^{***}	
		(0.018)	(0.018)	(0.018)	
No. observations	3528	3528	3528	3291	3155
Pseudo R2	0.027	0.093	0.093	0.101	0.028

Notes: Odds ratios are reported. Standard errors are in parentheses.
* p < 0.10, ** p < 0.05, *** p < 0.01.
All models use the same final analytical sample and probability weights.
All models control for child, maternal, socioeconomic, residence, regional and ANC variables.
Model 'Facility births' is restricted to facility deliveries. Model 'Vaginal births' excludes c-section births.

Table 11 RQ2 main results: average marginal effects - Nigeria

	(1) Facility	(2) + C-section	(3) Place type	(4) Facility births	(5) Vaginal births
Facility delivery	0.050***	0.068***			0.069***
	(0.015)	(0.015)			(0.015)
Public facility vs home			0.074***		
			(0.015)		
Non-public facility vs home			0.046**		
			(0.020)		
C-section		-0.215***	-0.214***	-0.240***	
		(0.018)	(0.018)	(0.023)	
No. observations	10109	10109	10109	4499	9568

Average marginal effects are reported in probability units; multiply by 100 for percentage points.
Standard errors in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 12 RQ2 main results: average marginal effects - Ghana

	(1) Facility	(2) + C-section	(3) Place type	(4) Facility births	(5) Vaginal births
Facility delivery	0.124^{***}	0.169^{***}			0.173^{***}
	(0.032)	(0.031)			(0.034)
Public facility vs home			0.167^{***}		
			(0.031)		
Non-public facility vs home			0.215^{***}		
			(0.045)		
C-section		-0.348^{***}	-0.351^{***}	-0.354^{***}	
		(0.025)	(0.025)	(0.026)	
No. observations	3828	3828	3828	3281	3158

Average marginal effects are reported in probability units; multiply by 100 for percentage points.
Standard errors in parentheses.
* p < 0.10, ** p < 0.05, *** p < 0.01.

Table 13 RQ2 main results: average marginal effects - Tanzania

	(1) Facility	(2) + C-section	(3) Place type	(4) Facility births	(5) Vaginal births
Facility delivery	0.141***	0.162***			0.165***
	(0.025)	(0.023)			(0.024)
Public facility vs home			0.166***		
			(0.023)		
Non-public facility vs home			0.101***		
			(0.037)		
C-section		-0.442***	-0.437***	-0.431***	
		(0.029)	(0.029)	(0.030)	
No. observations	4219	4219	4219	3502	3763

Average marginal effects are reported in probability units; multiply by 100 for percentage points.
Standard errors in parentheses.
* p < 0.10, ** p < 0.05, *** p < 0.01.

Table 14 RQ2 main results: average marginal effects - Zambia

	(1) Facility	(2) + C-section	(3) Place type	(4) Facility births	(5) Vaginal births
Facility delivery	0.115***	0.144***			0.145***
	(0.038)	(0.037)			(0.038)
Public facility vs home			0.146***		
			(0.037)		
Non-public facility vs home			0.094*		
			(0.053)		
C-section		-0.440***	-0.438***	-0.444***	
		(0.027)	(0.027)	(0.027)	
No. observations	3528	3528	3528	3291	3155

Average marginal effects are reported in probability units; multiply by 100 for percentage points.
Standard errors in parentheses.
* p < 0.10, ** p < 0.05, *** p < 0.01.

8 Discussion

One main finding of this study is that spatial accessibility is associated with institutional delivery in all four countries, but its specific meaning differs across national contexts. This finding is consistent with the theoretical framework of this thesis: spatial accessibility is a structural condition, but it does not operate through the same mechanism in every country. Instead, its role depends on the distribution of health facilities, the road network, institutional delivery coverage and the broader health-system context.

In Nigeria, the results are closer to a problem of access to health service points themselves. Nigeria has the lowest institutional delivery rate among the four countries, which means that a large proportion of women still do not enter the institutional delivery system. In this context, proximity to health facilities becomes a more prominent constraint. This interpretation is consistent with the Nigerian context discussed earlier: although Nigeria has a large absolute number of facilities, the supply is low relative to population size and many facilities are primary-level facilities with uneven service capacity. Therefore, the Nigerian results suggest that improving institutional delivery may require attention not only to road connection, but also to the spatial layout and functional availability of delivery-related health facilities.

By contrast, Ghana and Zambia point more strongly to the importance of road connection and transport accessibility. Both countries already have relatively high institutional delivery coverage, especially Zambia. In such settings, simply asking whether there is a facility nearby may no longer be sufficient to explain differences in facility delivery. Road connection may better capture whether women in less connected areas can reach facility-based care when labour begins. This interpretation is also consistent with the context section: Ghana has a large road network but still faces regional differences in road quality and referral distance, while Zambia has a relatively sparse higher-level road network and a large share of district and feeder roads. Thus, high institutional delivery coverage does not mean that spatial accessibility problems have disappeared. For Zambia in particular, road connection may still reflect whether women in rural and remote areas can reliably reach delivery services. This is in line with previous studies that emphasise the relationship between distance, transport and maternal health service use (Gabrysch et al. 2011; Dotse-Gborgbortsi et al. 2022; Scott et al. 2018).

The results for Tanzania show that both health facility distribution and road connection matter. This is consistent with the Three Delays Model, especially the second delay: delay in reaching care (Thaddeus and Maine 1994). Women need not only to be close to a facility that can provide delivery care, but also to have transport routes connecting their residential area to that facility. The Tanzanian context also helps explain this pattern. Institutional delivery has become relatively common after long-term expansion of primary healthcare infrastructure, but rural geography and road conditions remain important barriers. Therefore, in Tanzania, expanding the number of primary health facilities alone may not fully solve the problem. If road connections, referral pathways and transport conditions remain weak, women in remote areas may still face barriers when trying to use facility-based delivery care.

The results of RQ2 show that institutional delivery is positively associated with EIBF in all four countries. This may be because health facilities provide an environment in which mothers and newborns are more likely to obtain professional contact, postnatal observation and feeding support. This finding is consistent with the socio-ecological framework used in this thesis: EIBF is not only an individual feeding decision, but also a health practice shaped by the delivery environment, health workers and postnatal care routines. However, institutional delivery should be understood as an opportunity rather than a guarantee. Whether timely initiation of breastfeeding is actually achieved still depends on the delivery process and postnatal care practices. This also helps explain why some previous studies found that the relationship between place of delivery and EIBF is not always stable across settings (Duodu et al. 2021; Chipojola et al. 2020).

The caesarean section results further indicate that the relationship between institutional delivery and EIBF may be underestimated. Since caesarean section mainly occurs in health facilities, while caesarean section itself is associated with a lower likelihood of EIBF, the average EIBF level of the institutional delivery group will be pulled down by caesarean section cases (Yisma et al., 2019; Raihana et al., 2021). Therefore, the positive association between institutional delivery and EIBF becomes clearer after caesarean section is controlled for or excluded. This does not mean that caesarean section should be understood only as a negative practice, since it may be necessary for saving the lives of mothers and newborns. Rather, it means that facility delivery contains different delivery processes, and these processes can influence whether the supportive environment of the facility is translated into timely breastfeeding.

Taken together, the two research questions show where the main constraint lies in each country's service-use pathway. In Nigeria, the bottleneck appears earlier in the pathway. Low facility delivery, low EIBF and stronger health-facility accessibility results all point to limited entry into institutional delivery services. The positive but smaller EIBF association suggests that facility delivery still matters, but that, alongside improving early feeding support within facilities, greater attention is also needed to expand the reach of institutional delivery services themselves. In Ghana, Tanzania and Zambia, facility delivery is already much more common, and the link between facility delivery and EIBF is stronger. The remaining issue is therefore how to improve access to and benefits from facility-based environments among women who are still underserved. Tanzania demonstrates the importance of both facility and road accessibility, while Ghana and Zambia place greater emphasis on the role of road connectivity in shaping access to maternal and newborn care.

These country differences support the main argument of the thesis: the pathway from spatial accessibility to institutional delivery and then to EIBF exists across countries, but the weakest point in that pathway varies by national context. In Nigeria, the main problem is more closely related to the spatial distribution and functional accessibility of health service points. In Ghana and Zambia, road connection and rural transport conditions remain important even when institutional delivery coverage is high. In Tanzania, both facility distribution and road connection need to be considered together. This also reflects the distinction between contextual and compositional effects discussed in the theoretical framework. Individual and household characteristics matter, but the local service environment and transport structure also shape whether women can use institutional delivery and whether newborns can benefit from early postnatal support.

The theoretical contribution of this study is to place EIBF within a longer pathway of service utilization. EIBF occurs within one hour after birth, but the conditions that affect it do not only exist within this one-hour period. Whether women live near health facilities, whether they are connected to the main road network, whether they deliver in institutions, and whether the delivery involves caesarean section can all influence the realization of this early health practice. This is consistent with the theoretical framework of this study, which argues that maternal and child health behaviours are not determined only by individual knowledge or willingness, but are formed under the joint effects of spatial conditions, service systems and delivery processes.

In terms of policy, the results suggest that improving institutional delivery and promoting EIBF require distinguishing the main limiting factors in different countries. Nigeria needs to pay more attention to the spatial layout and functional accessibility of healthcare service points. Ghana and Zambia should continue to pay attention to road connection and rural transport conditions, because higher institutional delivery coverage does not mean that services are equally accessible to all areas. Tanzania needs to consider both the distribution of health facilities and road networks. Overall, improving EIBF cannot rely only on postnatal health education, but also needs to address upstream spatial inequality, institutional delivery opportunities and the quality of support within facility-based delivery care.

9 Limitations

This study has several limitations. First, DHS data are cross-sectional, so the analysis can identify associations but cannot establish causal relationships. Although the pathway from spatial accessibility to facility delivery and then to EIBF is theoretically meaningful, the models cannot fully rule out unobserved factors such as facility quality, family preferences, cultural norms or natural environment.

Second, the spatial variables are approximate. Public DHS coordinates are randomly displaced to protect respondents' privacy (urban up to 2 km, most rural points up to 5 km, and a 1% rural points within 10km). The distance variables represent approximate accessibility around the survey area, not exact household-level distance.

Third, OSM facility and road data may suffer from incomplete records, uneven updating, and cross-country differences in data quality. The health facility points do not necessarily identify facilities that actually provide delivery care, and road data do not fully capture paving, seasonal passability, and so on.

Fourth, the operationalisation of accessibility adopts a simplified approach. Health facility distance, major road distance, binary thresholds, accessibility typologies, and distance zones capture different aspects of access, none fully represents women's actual travel process. A road based distance to facility variable was therefore used only as a supplementary robustness measure. The road variable only includes trunk, primary, secondary roads and their link types, so it measures distance to the major road network rather than to all roads or local paths.

Fifth, some variables have interpretive limitations. Facility delivery indicates entry into a formal delivery-care environment, but it does not directly measure quality of care or breastfeeding support. EIBF is based on maternal recall and may involve reporting error. The c-section variable captures an important delivery process, but it cannot distinguish planned and emergency caesarean sections, postoperative care routines or mother–infant separation. ANC also requires careful interpretation because it reflects pre-delivery health-system contact, but may partly lie on the pathway from accessibility to facility delivery. For this reason, RQ1 estimates with ANC controls are interpreted as conditional associations.

Finally, the four countries are compared using the most recent DHS rounds available, but the survey years, health-system contexts and geographic data quality are not identical. The country-specific models help avoid masking national differences, but the results should not be read as one estimate for sub-Saharan Africa as a whole. Future research could combine DHS data with verified delivery-care facility lists, facility readiness data, detailed travel-time models, referral system information and postnatal care indicators to examine more directly how spatial accessibility, facility quality, delivery processes and breastfeeding support jointly shape early newborn health practices.

10 Conclusion

This study examined how spatial accessibility, institutional delivery and EIBF relate in Nigeria, Ghana, Tanzania and Zambia. By combining recent DHS individual data with externally derived spatial measures of health facility and major road access, the thesis analyse two links in the same pathway: whether spatial accessibility is associated with institutional delivery,and whether institutional delivery is associated with timely initiation of breastfeeding.

The results show that spatial accessibility is associated with institutional delivery, but the main spatial dimension differs across countries. In Nigeria, differences in institutional delivery are mainly related to proximity to health facilities. In Ghana and Zambia, road accessibility better captures spatial differences in institutional delivery, while Tanzania shows associations with both health facility distance and road connection. Areas far from both health facilities and major roads generally show lower institutional delivery, suggesting combined spatial disadvantage remains relevant, although its strength varies across national contexts.

The results also show that institutional delivery is positively associated with EIBF in all four countries. After accounting for caesarean section, this positive association becomes stronger, indicating that the advantage of facility delivery may be partly masked when caesarean and non-caesarean deliveries are analysed together. This finding highlights that facility delivery is not only a place of birth, but also a delivery-care environment whose effect on early breastfeeding depends on the delivery process and postnatal support.

The main contribution of this study is to place EIBF within a broader service-use pathway while showing that the spatial component differs across national contexts. By distinguishing the roles of facility proximity and major-road connection, the country-specific results avoid treating spatial accessibility as a uniform barrier across sub-Saharan Africa. Although EIBF occurs within one hour after birth, the conditions that shape it begin earlier: whether women live near health facilities, whether they are connected to the main road network, whether they deliver in a health facility, and what type of delivery process they experience. Therefore, EIBF is not only an individual feeding behaviour, but also as a practice shaped by spatial accessibility, health service use and delivery care.

In policy terms, the findings suggest that improving institutional delivery and promoting EIBF require different priorities across countries. Nigeria needs more attention to the spatial layout and functional accessibility of health facilities. Ghana and Zambia need continued attention to road connection and rural transport conditions, even when institutional delivery coverage is high. Tanzania requires attention to both facility distribution and road access. Overall, improving early breastfeeding practices requires not only postnatal health education, but also upstream improvements in spatial access, institutional delivery opportunities and breastfeeding support within facilities.

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Appendix A Supplementary analyses

Table A1. Heterogeneity in RQ1 associations by residence and household wealth

Panel A. Urban and rural residence

Model and variable	Nigeria		Ghana		Tanzania		Zambia	
	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
Unweighted N	3,777	6,332	1,526	2,262	769	2,921	986	2,305
Log-distance models								
Log health distance, ln(km+1)	0.894*** (0.037)	0.901** (0.044)	0.665*** (0.104)	0.798* (0.105)	1.113 (0.236)	0.707*** (0.057)	—	0.742** (0.101)
Log road distance, ln(km+1)	0.880 (0.078)	0.975 (0.050)	1.262 (0.316)	0.689*** (0.070)	0.744 (0.296)	0.813*** (0.054)	—	0.876 (0.073)
Binary-accessibility models								
Health facility within 5 km	1.351*** (0.145)	1.552*** (0.207)	2.530** (1.189)	1.152 (0.324)	0.570 (0.264)	2.232*** (0.507)	0.748 (0.445)	1.416 (0.402)
Major road within 10 km	2.335*** (0.716)	1.018 (0.113)	0.360 (0.265)	2.824*** (0.505)	4.294 (3.942)	1.368** (0.175)	3.228* (2.059)	1.638** (0.320)
Accessibility-typology model								
Near health + far road	3.619 (3.223)	0.460** (0.140)	2.511 (3.075)	0.674 (0.336)	0.200 (0.272)	0.917 (0.260)	0.296 (0.266)	0.789 (0.237)
Far health + near road	0.730*** (0.078)	0.795** (0.087)	0.692 (0.228)	0.733 (0.167)	1.521 (0.859)	0.854 (0.133)	1.671 (1.024)	1.027 (0.344)
Far health + far road	0.305*** (0.100)	0.869 (0.125)	1.743 (1.438)	0.267*** (0.069)	0.502 (0.571)	0.629*** (0.110)	0.493 (0.486)	0.527** (0.153)

Panel B. Household wealth

Model and variable	Nigeria		Ghana		Tanzania		Zambia	
	Middle or higher	Poorest or poorer	Middle or higher	Poorest or poorer	Middle or higher	Poorest or poorer	Middle or higher	Poorest or poorer
Unweighted N	5,288	4,821	1,591 / 1,579	2,189	2,148	1,665	1,710	1,793
Log-distance models								
Log health distance, ln(km+1)	0.828*** (0.032)	0.954 (0.051)	0.640*** (0.094)	0.797* (0.101)	0.798* (0.100)	0.722*** (0.072)	1.116 (0.233)	0.741** (0.096)
Log road distance, ln(km+1)	0.984 (0.063)	0.924 (0.056)	0.709 (0.177)	0.733*** (0.062)	0.716*** (0.076)	0.834** (0.070)	0.866 (0.147)	0.845* (0.077)
Binary-accessibility models								

Model and variable	Nigeria		Ghana		Tanzania		Zambia	
	Middle or higher	Poorest or poorer	Middle or higher	Poorest or poorer	Middle or higher	Poorest or poorer	Middle or higher	Poorest or poorer
Unweighted N	5,288	4,821	1,591 / 1,579	2,189	2,148	1,665	1,710	1,793
Health facility within 5 km	1.667*** (0.169)	1.231 (0.182)	2.104* (0.892)	1.245 (0.380)	2.049*** (0.552)	1.680* (0.472)	0.968 (0.424)	1.170 (0.331)
Major road within 10 km	1.135 (0.227)	1.064 (0.138)	7.308*** (4.201)	2.218*** (0.344)	1.712** (0.425)	1.340* (0.203)	1.526 (0.610)	1.841*** (0.415)
Accessibility-typology model								
Near health + far road	0.844 (0.476)	0.467** (0.176)	1.000 (0.000)	0.639 (0.309)	1.922 (1.053)	0.580 (0.214)	0.915 (0.503)	0.771 (0.251)
Far health + near road	0.584*** (0.054)	1.028 (0.136)	0.819 (0.247)	0.691 (0.168)	0.869 (0.211)	0.856 (0.161)	2.147 (1.186)	0.989 (0.353)
Far health + far road	0.538*** (0.118)	1.040 (0.177)	0.098*** (0.057)	0.326*** (0.081)	0.325*** (0.103)	0.694* (0.143)	1.014 (0.620)	0.444*** (0.135)

Notes: Entries are odds ratios; standard errors are in parentheses. The reference category for the accessibility typology is near health + near road. For Ghana's middle-or-higher wealth group, N = 1,591 in the log-distance and binary-accessibility models and N = 1,579 in the typology model. Estimates are rounded to three decimals. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A2. Robustness checks for RQ1 spatial-accessibility estimates

Panel A. Alternative typology: health facility within 10 km × major road within 2 km

Model and variable	Nigeria N = 10,109	Ghana N = 3,828	Tanzania N = 3,853	Zambia N = 3,528
Near health + far road	0.778** (0.089)	1.110 (0.346)	0.746 (0.143)	0.900 (0.311)
Far health + near road	0.698*** (0.065)	0.930 (0.214)	0.879 (0.195)	0.875 (0.318)
Far health + far road	0.765** (0.080)	0.559*** (0.126)	0.612** (0.117)	0.691 (0.238)

Panel B. Raw straight-line distances

Model and variable	Nigeria N = 10,109	Ghana N = 3,828	Tanzania N = 3,853	Zambia N = 3,528
Health distance, per 10 km	0.984 (0.012)	0.912* (0.046)	0.908*** (0.028)	0.952 (0.040)
Road distance, per 10 km	0.922 (0.056)	0.672*** (0.066)	0.786*** (0.064)	0.919** (0.035)

Panel C. Alternative standard-error specification

Model and variable	Nigeria N = 10,109	Ghana N = 3,828	Tanzania N = 3,853	Zambia N = 3,528
Log health distance, ln(km+1)	0.902** (0.040)	0.769*** (0.076)	0.776** (0.091)	0.854 (0.100)
Log road distance, ln(km+1)	0.973 (0.060)	0.772** (0.088)	0.801** (0.079)	0.859 (0.086)
Health facility within 5 km	1.423*** (0.166)	1.457* (0.309)	1.664* (0.497)	1.088 (0.253)
Major road within 10 km	1.040 (0.154)	2.409*** (0.577)	1.393* (0.279)	1.720** (0.379)
Near health + far road	0.499*** (0.096)	0.784 (0.391)	0.885 (0.491)	0.815 (0.231)
Far health + near road	0.765*** (0.077)	0.758 (0.152)	0.887 (0.169)	1.167 (0.331)
Far health + far road	0.813 (0.145)	0.317*** (0.091)	0.624* (0.161)	0.546** (0.147)

Panel D. Network health-facility distance

Model and variable	Nigeria N = 8,844	Ghana N = 3,267	Tanzania N = 3,752	Zambia N = 3,310
Network health distance, per 10 km	0.994 (0.009)	0.970 (0.020)	0.964* (0.019)	0.969 (0.025)
Road distance, per 10 km	0.914 (0.065)	0.737*** (0.069)	0.750*** (0.060)	0.931 (0.042)

Notes: Entries are odds ratios; standard errors are in parentheses. Panel A uses near health + near road as the reference category. Panel C reproduces the alternative clustered-standard-error results. Network-distance models use the available network-distance subsample. Estimates are rounded to three decimals. * p < 0.10, ** p < 0.05, *** p < 0.01.

Table A3. Sensitivity of RQ1 estimates to controls and antenatal-care adjustment

Model and variable	Nigeria	Ghana	Tanzania	Zambia
Specification order within each cell	M0 M1 M2	M0 M1 M2	M0 M1 M2	M0 M1 M2
Log distances				
Log distance to nearest health facility	0.830*** 0.870*** 0.902***	0.649*** 0.768*** 0.770***	0.717*** 0.770*** 0.776***	0.689*** 0.864 0.854
Log distance to nearest major road	0.611*** 0.944 0.973	0.529*** 0.730*** 0.772***	0.616*** 0.807*** 0.801***	0.736*** 0.821** 0.859*
Availability				
Health facility within 5 km	2.078*** 1.496*** 1.423***	2.468*** 1.362 1.457	3.426*** 1.694*** 1.664***	2.072*** 1.013 1.088
Major road within 10 km	1.612*** 1.092 1.040	4.568*** 2.622*** 2.409***	2.089*** 1.372** 1.393***	2.293*** 1.932*** 1.720***
Accessibility typology (10-km health / 10-km road thresholds)				
Near health + far road	0.391*** 0.586* 0.499**	0.441* 0.655 0.784	0.577** 0.925 0.885	0.560** 0.721 0.815
Far health + near road	0.660*** 0.758*** 0.765***	0.477*** 0.772 0.758	0.581*** 0.876 0.887	0.657* 1.165 1.167
Far health + far road	0.416*** 0.739** 0.813*	0.110*** 0.299*** 0.317***	0.254*** 0.624*** 0.624***	0.221*** 0.488*** 0.546**
Distance zones				
Health facility within 5 km	1.859*** 1.499*** 1.426***	2.360*** 1.436* 1.539*	2.637*** 1.630** 1.592**	2.337*** 1.114 1.174
Major road within 2 km	2.170*** 1.117 1.050	5.552*** 2.651*** 2.354***	3.359*** 1.581*** 1.618***	2.352*** 1.803** 1.595*
Health distance: 5–10 km	0.952 1.016 1.011	1.529** 1.239 1.225	0.938 0.981 0.965	1.620** 1.238 1.188
Road distance: 2–10 km	1.091 1.070 1.031	3.381*** 2.449*** 2.308***	1.523*** 1.294* 1.315**	2.076*** 1.992*** 1.784**
DHS geospatial-covariate travel time				
DHS geospatial-covariate travel time, per 10 units	0.776*** 0.956*** 0.974**	0.903*** 0.949*** 0.955***	0.951*** 0.971*** 0.971***	0.964*** 0.991 0.994

Notes: Cells report odds ratios in the order M0/M1/M2. M0 includes no controls; M1 includes controls excluding antenatal care (ANC); M2 includes controls including ANC. Nigeria: N = 10,109; Ghana: N = 3,828; Tanzania: M0 N = 4,219; M1/M2 N = 3,853; Zambia: N = 3,528. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A4. Threshold sensitivity of RQ1 spatial-accessibility measures

Panel A. Weighted share of observations within each threshold

Threshold	Nigeria N = 10,109	Ghana N = 3,828	Tanzania N = 4,219	Zambia N = 3,528
Health facility within 2.5 km	14.2%	19.9%	21.3%	25.0%
Health facility within 5 km	24.1%	34.4%	29.8%	45.2%
Health facility within 10 km	38.9%	50.5%	45.8%	62.1%
Health facility within 15 km	48.3%	64.6%	59.2%	73.0%
Health facility within 20 km	59.3%	74.1%	66.4%	77.6%
Major road within 2 km	53.2%	50.4%	46.5%	37.4%
Major road within 5 km	76.8%	73.6%	65.8%	51.5%
Major road within 10 km	89.5%	88.9%	80.8%	62.1%
Major road within 15 km	94.6%	95.2%	90.0%	68.8%
Major road within 20 km	96.9%	96.8%	95.4%	74.9%

Panel B. Single-threshold models

Threshold	Nigeria N = 10,109	Ghana N = 3,828	Tanzania N = 3,853	Zambia N = 3,528
Health facility within 2.5 km	1.179* (0.098)	1.897** (0.306)	1.498 (0.247)	1.151 (0.313)
Health facility within 5 km	1.426*** (0.083)	1.563* (0.230)	1.665*** (0.196)	1.155 (0.230)
Health facility within 10 km	1.243*** (0.072)	1.598*** (0.169)	1.230 (0.132)	1.261 (0.187)
Health facility within 15 km	1.136* (0.069)	1.684*** (0.147)	1.413*** (0.122)	1.785*** (0.191)
Health facility within 20 km	1.152** (0.067)	1.352** (0.145)	1.615*** (0.122)	1.653** (0.197)
Major road within 2 km	1.030 (0.073)	1.373* (0.163)	1.425*** (0.136)	1.175 (0.235)
Major road within 5 km	1.070 (0.082)	1.687*** (0.160)	1.557*** (0.115)	1.281 (0.206)
Major road within 10 km	1.070 (0.105)	2.471*** (0.166)	1.392*** (0.125)	1.733*** (0.187)
Major road within 15 km	1.103 (0.146)	2.575*** (0.181)	1.594*** (0.153)	1.827*** (0.177)
Major road within 20 km	1.032 (0.196)	3.152*** (0.217)	2.245*** (0.224)	1.755*** (0.173)

Table A4 (continued)

Panel C. Far from both health facilities and major roads across alternative thresholds

Health / road threshold	Nigeria N = 10,109	Ghana N = 3,828	Tanzania N = 3,853	Zambia N = 3,528
5 km / 2 km	0.657*** (0.114)	0.599* (0.300)	0.419*** (0.240)	0.845 (0.408)
5 km / 5 km	0.667*** (0.116)	0.474*** (0.283)	0.374*** (0.228)	0.761 (0.305)
5 km / 10 km	0.683*** (0.132)	0.286*** (0.281)	0.396*** (0.240)	0.573* (0.290)
5 km / 15 km	0.656** (0.166)	0.261*** (0.284)	0.396*** (0.244)	0.528** (0.292)
5 km / 20 km	0.704* (0.210)	0.211*** (0.311)	0.259*** (0.307)	0.541** (0.281)
10 km / 2 km	0.765** (0.105)	0.559*** (0.226)	0.612** (0.192)	0.691 (0.344)
10 km / 5 km	0.798** (0.107)	0.433*** (0.206)	0.544*** (0.171)	0.715 (0.276)
10 km / 10 km	0.813* (0.124)	0.317*** (0.220)	0.624*** (0.169)	0.546** (0.256)
10 km / 15 km	0.770 (0.160)	0.267*** (0.230)	0.522*** (0.192)	0.508*** (0.244)
10 km / 20 km	0.840 (0.208)	0.227*** (0.253)	0.353*** (0.264)	0.501*** (0.245)
15 km / 2 km	0.863 (0.101)	0.510*** (0.204)	0.521*** (0.188)	0.449** (0.333)
15 km / 5 km	0.891 (0.105)	0.418*** (0.182)	0.442*** (0.171)	0.461*** (0.283)
15 km / 10 km	0.883 (0.126)	0.333*** (0.182)	0.517*** (0.168)	0.360*** (0.265)
15 km / 15 km	0.845 (0.160)	0.284*** (0.209)	0.481*** (0.183)	0.366*** (0.243)
15 km / 20 km	0.914 (0.207)	0.238*** (0.235)	0.399*** (0.263)	0.331*** (0.257)
20 km / 2 km	0.885 (0.100)	0.580*** (0.208)	0.439*** (0.190)	0.504** (0.326)
20 km / 5 km	0.880 (0.110)	0.486*** (0.191)	0.381*** (0.175)	0.495** (0.284)
20 km / 10 km	0.820 (0.135)	0.392*** (0.189)	0.461*** (0.177)	0.367*** (0.272)
20 km / 15 km	0.773 (0.174)	0.304*** (0.226)	0.418*** (0.201)	0.377*** (0.252)
20 km / 20 km	0.925 (0.205)	0.292*** (0.237)	0.468*** (0.274)	0.366*** (0.257)

Notes: Panel A reports survey-weighted percentages. Panels B and C report odds ratios with standard errors in parentheses. In Panel C, each estimate is for the far-health + far-road category under the stated health/road threshold pair; the reference category is near health + near road. Ghana has N = 3,821, rather than 3,828, for the 5-km health/15-km road combination. Estimates are rounded to three decimals. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A5. Sensitivity of RQ2 results to an inclusive EIBF definition

Model and estimate	Nigeria	Ghana	Tanzania	Zambia
Line order within each cell	Odds ratio (SE) Average marginal effect (SE)	Odds ratio (SE) Average marginal effect (SE)	Odds ratio (SE) Average marginal effect (SE)	Odds ratio (SE) Average marginal effect (SE)
Facility-delivery model	N = 10,109	N = 3,828	N = 4,219	N = 3,528
Facility delivery	1.081 (0.068) 0.019 (0.015)	1.984*** (0.297) 0.134*** (0.031)	1.768*** (0.252) 0.076*** (0.021)	1.752*** (0.341) 0.089** (0.035)
Facility delivery + caesarean section	N = 10,109	N = 3,828	N = 4,219	N = 3,528
Facility delivery	1.188*** (0.076) 0.041*** (0.015)	2.859*** (0.447) 0.188*** (0.029)	2.366*** (0.347) 0.103*** (0.019)	2.395*** (0.471) 0.126*** (0.033)
Caesarean section	0.286*** (0.035) -0.269*** (0.021)	0.171*** (0.022) -0.353*** (0.026)	0.090*** (0.014) -0.414*** (0.030)	0.099*** (0.013) -0.440*** (0.028)
Place-of-delivery type + caesarean section	N = 10,109	N = 3,828	N = 4,219	N = 3,528
Public facility vs home	1.233*** (0.082) 0.050*** (0.016)	2.839*** (0.444) 0.187*** (0.029)	2.410*** (0.355) 0.105*** (0.019)	2.405*** (0.474) 0.127*** (0.033)
Non-public facility vs home	1.038 (0.091) 0.009 (0.021)	3.318*** (0.849) 0.210*** (0.041)	1.841** (0.493) 0.077** (0.031)	2.123** (0.657) 0.112** (0.045)
Caesarean section	0.289*** (0.036) -0.267*** (0.022)	0.170*** (0.022) -0.355*** (0.026)	0.091*** (0.014) -0.411*** (0.030)	0.099*** (0.013) -0.439*** (0.028)
Facility deliveries only	N = 4,499	N = 3,281	N = 3,502	N = 3,291
Caesarean section	0.289*** (0.036) -0.279*** (0.024)	0.172*** (0.022) -0.344*** (0.027)	0.092*** (0.014) -0.383*** (0.029)	0.096*** (0.013) -0.440*** (0.028)
Vaginal deliveries only	N = 9,568	N = 3,158	N = 3,763	N = 3,155
Facility delivery	1.184*** (0.076) 0.041*** (0.016)	2.682*** (0.429) 0.170*** (0.031)	2.395*** (0.360) 0.095*** (0.019)	2.441*** (0.480) 0.122*** (0.033)

Notes: Inclusive EIBF includes immediate initiation, initiation within the first hour and initiation reported as exactly one hour after birth. The first line in each cell is an odds ratio; the second is an average marginal effect in probability units. Robust standard errors are in parentheses. Models use probability weights and adjust for child sex, singleton birth, birth order, maternal age, marital status, education, household wealth, residence, region and ANC. The facility-deliveries model is restricted to facility births; the vaginal-deliveries model excludes caesarean births. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A6. Subgroup-specific RQ2 average marginal effects of facility delivery

Subgroup	Nigeria N = 10,109	Ghana N = 3,828	Tanzania N = 4,219	Zambia N = 3,528
Panel A. Maternal age at birth				
15-19	-0.003 (0.038)	0.255*** (0.082)	0.092* (0.055)	0.139* (0.078)
20-24	0.078*** (0.025)	0.142** (0.059)	0.101** (0.042)	0.124* (0.069)
25-34	0.090*** (0.019)	0.196*** (0.042)	0.211*** (0.036)	0.196*** (0.059)
35-49	0.036 (0.028)	0.111* (0.058)	0.188*** (0.048)	0.064 (0.085)
Interaction p-value	0.056	0.439	0.083	0.643
Panel B. Birth order				
First birth	0.007 (0.025)	0.191*** (0.061)	0.040 (0.059)	0.116 (0.086)
Second birth	0.107*** (0.027)	0.238*** (0.065)	0.186*** (0.054)	0.160** (0.081)
Third birth	0.101*** (0.030)	0.226*** (0.075)	0.109** (0.051)	0.226*** (0.080)
Fourth or higher	0.067*** (0.020)	0.121*** (0.040)	0.195*** (0.030)	0.111** (0.052)
Interaction p-value	0.020	0.313	0.059	0.595
Panel C. Household wealth				
Poorest	0.063** (0.029)	0.122*** (0.038)	0.150*** (0.035)	0.082 (0.052)
Poorer	0.083*** (0.028)	0.116* (0.060)	0.185*** (0.043)	0.175** (0.070)
Middle	0.093*** (0.027)	0.235*** (0.069)	0.194*** (0.051)	0.176** (0.081)
Richer	0.037 (0.028)	0.284** (0.129)	0.170** (0.068)	0.267** (0.123)
Richest	0.047 (0.046)	0.518*** (0.098)	-0.124* (0.066)	0.127 (0.278)
Interaction p-value	0.546	0.145	0.039	0.639
Panel D. Urban-rural residence				
Urban	0.066*** (0.022)	0.222*** (0.070)	0.111 (0.075)	0.190** (0.083)
Rural	0.070*** (0.018)	0.153*** (0.032)	0.168*** (0.024)	0.130*** (0.040)
Interaction p-value	0.771	0.341	0.440	0.515
Panel E. Maternal education				
No education	0.055** (0.023)	0.104** (0.041)	0.166*** (0.036)	0.002 (0.094)
Primary	0.101*** (0.034)	0.262*** (0.061)	0.177*** (0.030)	0.174*** (0.047)
Secondary	0.077*** (0.021)	0.166*** (0.049)	0.045 (0.058)	0.148** (0.067)
Higher	-0.019 (0.059)	0.675*** (0.038)	0.126** (0.052)	0.279 (0.377)

Subgroup	Nigeria N = 10,109	Ghana N = 3,828	Tanzania N = 4,219	Zambia N = 3,528
Interaction p-value	0.252	0.000	0.139	0.460

Notes: Entries are corrected average marginal effects of facility delivery in probability units; robust standard errors are in parentheses. Each effect is the adjusted difference P(EIBF | facility delivery = 1) - P(EIBF | facility delivery = 0) at the stated subgroup level. Interaction p-values are joint Wald tests. Models use probability weights, control for caesarean section and include the main RQ2 covariates except the panel moderator. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A7. Survey-weighted EIBF proportions under strict and inclusive definitions

Country	Strict EIBF (%)	Inclusive EIBF (%)
Nigeria	36.8	48.7
Ghana	60.1	73.3
Tanzania	75.0	84.8
Zambia	70.4	82.5

Notes: Survey-weighted proportions in the final analytical sample. Strict EIBF follows the main thesis definition. Inclusive EIBF additionally classifies initiation reported as exactly one hour after birth as timely.

Appendix B AI Statement

During the completion of the thesis, ChatGPT was mainly used in three ways. First, it was used for coding assistance during the empirical analysis process, particularly for understanding the causes of error messages that I could not independently resolve and the logic behind possible modifications. Second, it was used to improve literature search strategies, especially in cases where many different terms had similar meanings and I was uncertain whether my choice of keywords would identify the most appropriate literature. Third, it was used for grammar and wording when I was uncertain between several alternative expressions and asked for comparisons between them. No part of the thesis text was generated directly by AI.