Essays on the impact of the National Health Insurance Scheme of Ghana

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ABSTRACT

English

Universal Health Coverage (UHC) refers the idea that all people should be able to use any health services they require without incurring financial hardship. It is a concept that the World Health Organization (WHO) and United Nations have been promoting in recent times as an essential health system goal and mechanism for sustainable development. Few low- and middle-income countries (LMICs) have implemented UHC. The National Health Insurance Scheme (NHIS) of Ghana is one of the few examples and, as such, provides a unique opportunity to understand how UHC reforms may be designed and implemented to achieve the goals of UHC in LMICs.

While several studies have been published on the impact of the NHIS, important gaps still remain in the literature. In particular, our understanding of 1) its impact on population health outcomes, 2) how equitable any such impact has been at the population level, and 3) the mechanisms underlying such impact, is incomplete. In this dissertation, I set out to contribute to addressing these knowledge gaps by examining the impact of the NHIS on population-wide healthcare utilization and early childhood mortality, its effect on rural-urban inequalities in early childhood mortality, and the role of healthcare utilization (which the policy most directly targets) in driving rural-urban inequalities in early childhood mortality. This dissertation is organized into three manuscripts.

In the first manuscript, I assessed the population-wide impact of the NHIS on antenatal care usage, skilled attendance at delivery, neonatal mortality and infant mortality, using data from the Demographic and Health Surveys (DHS), and a difference-in-differences approach. I

found that the NHIS increased antenatal care (ANC) usage (defined as having the WHO-recommended minimum of four antenatal care visits during the pregnancy) by 10.5 [8.2, 12.5][a] percentage points with the largest increases seen among mothers in the richest quintile (increase of 15.0 [10.0, 20.1] percentage-points) and those with at least a secondary education (increase of 8.9 [4.8, 13.3] percentage points). The policy increased skilled attendance by 6.1 [4.0, 7.8] percentage-points. As with antenatal care usage, the second richest quintile and mothers with at least a primary school education saw the most benefit (11.2 [7.2, 14.9] and 3.7 [0.5, 6.8] percentage-point increases respectively). The two poorest wealth quintiles were actually worse-off after the policy was implemented (-5.3 [-8.1, -2.2] and -5.3 [-8.1, -2.2] percentage-point changes in skilled attendance rates respectively).

Notably, the impact of the policy on skilled attendance was completely attenuated when the data was restricted to children born before 2008 indicating that most of the observed effect could be attributed to the Free Maternal Health policy introduced in 2008. I found no evidence that the policy affected neonatal or infant mortality rates, either across the entire population or within strata of household wealth or maternal education.

In the second manuscript, I examined how the advent of the NHIS policy affected levels and trends[b] in rural-urban inequalities neonatal and infant mortality rates, for children born in Ghana between 1993 and 2013. I used data on births from the Ghana DHS surveys (from the years 1993, 1998, 2003, 2008 and 2013), and an interrupted time series study approach.

[a] Throughout this work, results will be presented as estimates with 95% confidence limits in square brackets. Values in square brackets may be assumed to be 95% confidence limits unless otherwise stated

[b] Trend refers to the slope of the rate of change in the outcome per year. In this instance, the rate of change in the rural-urban inequality in neonatal and infant mortality rates per year

I found an average rural-urban inequality in infant mortality of 13.3 [6.4, 20.8] deaths per 1000 live births in the pre-intervention period, to the disadvantage of rural dwellers. This disparity essentially disappeared in the post-intervention period (disparity in neonatal mortality levels = -4.1 [-12.7, 5.5] death per 1000 live births) representing a change of -17.5 [-28.8, -5.8] deaths per 1000 live births in the rural-urban inequality attributable to the NHIS. There was no discernible trend in either rural or urban infant mortality in the pre-intervention period and no discernible change in levels or trends in neonatal mortality before or after the implementation of the policy.

In the final manuscript, I explored the role of skilled attendance[c] as a contributor to rural-urban inequalities in neonatal and infant mortality. I used data from the DHS for Ghana (from the years 1993, 1998, 2003, 2008 and 2013), and applied the VanderWeele 3-way decomposition of mediation and interaction effects. This approach decomposes the total effect of an exposure on an outcome through a measured mediator, into a component purely due to mediation (pure indirect effect), a component due to both interaction and mediation (mediated interaction), and a component due to neither mediation nor interaction (the pure direct effect). I adapted this approach to disaggregate the rural-urban disparities in neonatal and infant mortality into the independent contributions of rural-urban residence (both direct and mediated by skilled attendance at delivery), and the joint effects of both rural-urban residence and skilled attendance.

[c] Skilled attendance was defined as birth attended by a trained person and which occurs in an appropriate setting. Trained person was defined as either a doctor, midwife, nurse or other accredited medical professional and excluded traditional birth attendants. Appropriate place included hospitals, clinics, accredited maternity homes and excluded births which occurred at home or in transit to a health facility.

After accounting for socio-economic and cultural factors, I found a total rural-urban disparity in infant mortality of 3.6 [-9.8, 14.6] deaths per 1000 live births to the disadvantage of rural dwellers. This was made up of a pure indirect component of 4.2 [0.9, 8.3] per 1000 live births, a mediated interaction component of -4.1 [-8.6, -0.4] deaths per 1000 live births and a pure direct effect of 3.6 [-9.8, 14.6] per 1000 live births. For neonatal mortality, the corresponding values were a total rural-urban of 5.5 [-3.3, 14.8] deaths per 1000 live births a pure direct effect of 6.1 [-2.6, 15.8], a pure indirect effect of 2.0 [-0.3, 4.4] and a mediated interaction of -2.6 [-5.3, -0.1] deaths per 1000 live births.

These findings suggest that skilled attendance plays an important role in driving disparities in infant mortality and that its contribution is both from differences in its distribution between rural and urban areas, as well as differences in its effect on mortality between urban and rural areas. Thus, beyond the availability of skilled attendance services, attention should be paid to the quality of healthcare services when planning healthcare services policy.

In all, I found that the NHIS improved antenatal care and skilled attendance for the general population and also improved rural-urban disparities in infant mortality. Finally, I found that skilled attendance mediates rural-urban disparities in infant mortality, apparently by virtue of having a differential impact on infant mortality among rural- and urban-born children.

In conclusion, the NHIS appears to be improving healthcare utilization, but not early childhood outcomes for the population of Ghana overall. It has however helped to improve rural-urban disparities in infant mortality—disparities that appear to be driven in at least in part by differences in the distribution and quality of skilled attendance between urban and rural areas.

French

La couverture santé universelle (CSU) renvoie à l'idée que toutes les personnes devraient pouvoir utiliser les services de santé dont elles ont besoin sans subir de difficultés financières. C'est un concept que l'Organisation mondiale de la santé (OMS) et les Nations Unies ont récemment promu comme objectif essentiel du système de santé et mécanisme de développement durable. Peu de pays à revenu faible ou intermédiaire ont mis en place la CSU. Le régime national d'assurance maladie du Ghana est l'un des rares exemples et offre, à ce titre, une occasion unique de comprendre comment les réformes de la CSU peuvent être conçues et mises en œuvre pour atteindre les objectifs de la CSU dans les PFR-PRI.

L'évaluation formelle de l'impact causal du SNIS sur les résultats pour la santé de la population n'a toujours pas retenu l'attention dans la littérature sur la santé mondiale. Il reste urgent de comprendre son impact sur les résultats distaux, tels que la mortalité, et le caractère équitable de son impact sur tous les groupes socio-économiques, ainsi que sur les mécanismes sous-jacents à cet impact. Dans cette thèse, je vais combler ces lacunes dans les connaissances en examinant l'impact du SNIS sur l'utilisation des soins de santé et la mortalité infantile dans l'ensemble de la population, ses effets sur les différences entre les niveaux rural et urbain et les tendances en matière de mortalité infantile, ainsi que sur le rôle de la population. l'utilisation des soins de santé, qu'elle cible le plus directement, pour réduire les disparités entre les zones rurales et les zones urbaines en matière de mortalité infantile. Cette thèse est organisée en trois manuscrits.

Dans le premier manuscrit, j'évalue l'impact du SNIS sur l'ensemble de la population sur l'utilisation des soins prénatals, l'assistance qualifiée à l'accouchement et la mortalité

néonatale et infantile, à l'aide des données des enquêtes démographiques et de santé (EDS), et d'une différence de différence approche avec plusieurs pays de contrôle. J'ai constaté que le NHIS augmentait l'utilisation des soins prénatals de 10,5 [8.2, 12.5] points de pourcentage (les valeurs entre crochets représentaient une limite de confiance de 95%), les augmentations les plus importantes étant observées parmi les quintiles de richesse les plus élevés (15,0 [10,0, 20,1] points de pourcentage) et les mères ayant au moins un diplôme d'études secondaires (16.2 [12.2, 20.1]). De même, la plus grande amélioration de la couverture des soins prénatals a été constatée chez les mères sans éducation (12,5 [IC 95%: 5,8, 19,4] points de pourcentage). La politique a augmenté la formation qualifiée de 6,1 [4,0, 7,8] points de pourcentage. Les deux quintiles les plus pauvres étaient en réalité moins bien lotis après l'application de la politique (-5,3 [-8,1, -2,2] et -5,3 [-8,1, -2,2] points de pourcentage des taux d'accouchement qualifiés, respectivement), tandis que le deuxième quintile le plus riche Les mères ayant au moins un niveau d'instruction primaire ont vu le plus d'avantages (11,2 [7,2, 14,9] et 9,1 [5,1, 13,6] augmentations respectivement). L'impact de la politique sur l'accouchement qualifié a été totalement atténué lorsque les données ont été limitées aux enfants nés avant 2008, ce qui indique que la plupart des effets observés pourraient être attribués à la politique de santé maternelle et gratuite mise en place à cette époque. Je n'ai trouvé aucune preuve que la politique ait eu une incidence sur les taux de mortalité néonatale ou infantile, que ce soit dans l'ensemble de la population ou dans les strates de la richesse du ménage ou de l'éducation maternelle.

Dans le deuxième manuscrit, j'ai examiné l'incidence de l'avènement de la politique NHIS sur les différences entre niveaux et tendances des taux de mortalité néonatale et néonatale entre zones rurales et urbaines entre 1993 et 2013. J'ai utilisé les données sur les naissances

des enquêtes DHS du Ghana (à partir des années 1993)., 1998, 2003, 2008 et 2013) et une approche d'étude de série temporelle interrompue.

J'ai trouvé une disparité rurale-urbaine en matière de mortalité infantile au cours de la période précédant l'intervention de 13,3 [6,4, 20,8] décès pour 1 000 naissances vivantes, au détriment des habitants des zones rurales. Cette disparité a pratiquement disparu après l'intervention (disparité des niveaux = -4,1 [-12,7, 5,5] décès pour 1 000 naissances vivantes). Cela représente un changement de -17,5 [-28,8, -5,8] décès pour 1 000 naissances vivantes dans la disparité entre zones rurales et zones urbaines attribuable à la NHIS. Il n'y avait pas de tendance perceptible de la mortalité infantile rurale ou urbaine dans la période pré-intervention, mais après l'intervention, la mortalité infantile rurale a commencé à diminuer de -4,4 [-7,8, -0,3] décès pour 1000 naissances vivantes. Il n'y a pas eu de changement perceptible des niveaux ou des tendances de la mortalité néonatale avant ou après la mise en œuvre de la politique.

Dans le dernier manuscrit, j'ai exploré le rôle de l'assistance qualifiée lors de l'accouchement en tant que facteur contribuant aux disparités entre les zones rurales et urbaines en matière de mortalité néonatale et infantile. De nouveau, j'ai utilisé les données de l'EDS pour le Ghana (pour les années 1993, 1998, 2003, 2008 et 2013), et appliqué la décomposition à trois voies de VanderWeele des effets de médiation et d'interaction. Cette approche décompose l'effet total d'une exposition sur un résultat obtenu par le biais d'un médiateur mesuré en une composante purement due à la médiation (effet purement indirect) et une composante due à la fois à l'interaction et à la médiation (interaction médiée) et une composante due à la médiation ni interaction (l'effet direct pur). J'ai adapté cette approche pour ventiler les disparités entre zones rurales et urbaines en matière de néonatologie et d'infan

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CONTRIBUTIONS TO ORIGINAL KNOWLEDGE

In this dissertation, I set out to bridge gaps in the current literature on the impact of the National Health insurance Scheme of Ghana on health outcomes with consideration given to the equity dimensions of that impact as well.

This dissertation provides the following insights into the role of social health insurance schemes in bridging equity gaps in health outcomes in low- and middle-income countries:

1. The NHIS of Ghana has improved the use of antenatal care services and skilled attendance in Ghana as a whole
2. The improvements in utilization of antenatal care services and skilled delivery have been concentrated among women of higher socio-economic status
3. There was no evidence that the policy has improved early childhood mortality at the population level
4. The NHIS has improved rural-urban disparities in infant mortality, though we found no evidence that it has also improved disparities in neonatal mortality
5. Rural dwellers who use skilled attendance have a higher-than-expected level of infant mortality
6. Rural-urban disparities in infant mortality are driven not only by differences in the distribution of skilled attendance between rural and urban areas but by differences in the effect of skilled attendance on infant mortality between rural and urban areas

CONTRIBUTION OF AUTHORS

All three manuscripts in this thesis were conceptualized by Oduro Oppong-Nkrumah (ON) under the guidance of Drs. Jay Kaufman (JK) and Arijit Nandi (AN). The analysis plans were decided after discussions by ON, JK and AN. ON conducted all analyses and wrote all 3 manuscripts. JK and AN read and commented on all manuscripts. Their comments were incorporated in the form of substantial revisions to the manuscripts. ON is the first author on all three manuscripts in the thesis.

1 INTRODUCTION

1.1 Background

In this thesis, I examined the population-level impact of the National Health Insurance Scheme of Ghana (NHIS), in relation to early childhood mortality. I investigated the question of whether this impact has been equitable and explored the mechanisms by which such equity might have been achieved. The NHIS is the major health system reform program implemented in Ghana over the past 20 years.[1] As one of the few examples of a successfully implemented, national-level Universal Health Coverage (UHC) policy in sub-Saharan Africa,[2,3] the NHIS provides an opportunity to learn about the impact of such policies in this region in particular, and in low- and middle-income countries in general. Such knowledge should hopefully inform the planning and implementation of similar initiatives in similar contexts in the future.

UHC has emerged as a key goal of health systems worldwide, in recent times.[4,5] Academics, policy-thinkers and decision-makers are focusing more and more on the financial impact of illness on individuals, households and healthcare systems at large, even while they seek avenues to expand access to healthcare. Particular effort is being put into understanding and developing approaches to reduce the financial harm that can result from catastrophic medical costs associated with severe and/or prolonged illness. It has been estimated that catastrophic medical costs force up to 150 million households into poverty annually.[6–8] In India alone, 60 million households were estimated to have been impoverished by illness in 2011.[9,10]

UHC policies have emerged as arguably the preferred policy response to the challenge of expanding healthcare access and mitigating catastrophic medical costs in a sustainable and equitable manner.[4,11–13] Global interest in the concept of UHC has developed rapidly over the

past decade both in academic and policy circles, with numerous articles written on the subject[14–20] and many UHC policy initiatives under trial or already implemented in various countries. This surge of interest in UHC has earned it the moniker of the "third global health transition."[4] Unlike the demographic and epidemiological transitions (the other two global transitions),[21,22] which were driven by underlying population and disease dynamics, the UHC phenomena reflects a widespread policy response to a prevalent social need. The global extent of the clamor for UHC can also be seen in the prominence it has received from the World Health Organization (WHO)—being the subject of the 2010 World Health Report and the theme of the 65th World Health Assembly.[4,11] The Director General of the WHO, Margaret Chan has gone as far as to describe UHC as "the single most powerful concept that public health has to offer.[23]"

1.1.1 Universal Health Coverage

In essence, UHC refers to any of a varied mix of approaches to healthcare financing, which are all aimed at reducing out-of-pocket medical expenditure (OOPE), and improving access to healthcare.[4,11] The WHO has defined UHC to mean a situation in which "…all people and communities can use the promotive, preventive, curative, rehabilitative and palliative health services they need, of sufficient quality to be effective, while also ensuring that the use of these services does not expose the user to financial hardship.[24,25]"

The designation "Universal" in UHC as used in this work, does not always imply that absolutely everyone in each country in which a specific UHC policy is implemented is necessarily covered by the policy in question. It refers rather to the aspiration of such policies to contribute to extending coverage to everyone. Indeed, few countries have a single UHC policy that applies to every resident of that country. Many countries have multiple coexisting health financing mechanisms, which apply to different subsets of the population at any

particular time.[26,27] For the purposes of this work, I will use the designation "UHC policy" in this dissertation to refer to policies that aim to increase healthcare access and financial protection, without considering the actual extent of coverage achieved by those policies.

The concept of UHC is founded on three pillars: 1) equitable access to healthcare services, 2) improvement of health outcomes through the provision of quality healthcare services, and 3) protection from financial risk associated with adverse health events.[28–30] Put another way, achieving UHC requires that anyone who needs healthcare services should be able to access care irrespective of their socio-economic circumstances, that the healthcare service so received should be of high enough quality to actually improve outcomes for the person in question, and finally that the person should not incur financial harm as a consequence of using such healthcare.[31,32]

At its core, UHC echoes the idea of health as a fundamental human right, proposed in the WHO constitution in 1948, and subsequently promoted through a succession of initiatives including the Health-for-All agenda set forth in the Alma Ata declaration of 1978, and most recently, the health-related Sustainable Development Goals (SDGs).[33–37]

The concept of UHC is not new. Perhaps the first successful implementation of such an idea in modern times was the social insurance scheme established in 19th-century Germany under Otto von Bismarck.[38] This scheme pioneered many key hallmarks of UHC and remains the archetype of many such schemes.

The idea of UHC has however only recently taken root in low- and middle-income countries. The spread of UHC in these countries has often been hampered by a lack of the institutional and

financial foundation necessary to support the requisite resource mobilization and service provision.[2,39] However, as the devastating impact of catastrophic medical expenditure on households has gained more and more attention we have seen many of even the poorest developing countries initiate programs to provide financial protection for their people in the event of illness. In sub-Saharan Africa, we have seen the establishment of programs such as the Mutuelles scheme in Rwanda and the National Hospitals Insurance Fund of Kenya.[40] Among these, Ghana's much-heralded NHIS has arguably been one of the most successful.

1.1.2 The National Health Insurance Scheme of Ghana

From the 1980s to 2003, healthcare in Ghana was financed by a fee-for-service system known in local parlance as "cash-and-carry." Like other user-fee-based systems, it was found to place substantial financial barriers in the way of accessing healthcare, especially for the poor.[41,42] The NHIS was established by an act of parliament, the National Health Insurance Scheme Law, Act 650, in 2003 and its implementation nationwide was completed by 2004.[43–46] The law established a National Health Insurance Council to govern the provision of health insurance in Ghana.[43]

The NHIS may be described in a nutshell as a single-payer financing mechanism for healthcare in Ghana. The structure of the NHIS has changed considerably since its inception. It was initially organized as a network of semi-autonomous district mutual health insurance schemes overseen and regulated by a National Health Insurance Authority (NHIA). The NHIA also administered the central pool of tax funds with which the whole scheme was funded. Each district mutual health insurance scheme enrolled its own members and contracted with local health providers to provide services to their clients. Members registered with one district mutual scheme would require authorization to access care from providers not registered with that scheme. The district

mutual health insurance schemes would make claims for services provided to their clients from the central funding pool through the NHIA.[42,47–49]

This system eventually evolved into a centralized national structure with the NHIA as the single payer. In this new role, the NHIA is responsible for negotiating with providers, defining benefits, registering members and reimbursing providers across the country. The erstwhile district mutual schemes have been absorbed into this structure as local offices of the national authority. Membership of the NHIS currently requires annual registration with the NHIA through its local offices and payment of an annual premium. Members are provided with a health card which grants them access to care from any registered provider anywhere in the country.[50–52]

The NHIS is mainly funded by a 2.5% special value-added tax (VAT) levy on most goods and services bought and sold in Ghana. Enrollees are also required to pay an annual premium. The premium amount is supposed to vary based on income, but this has proven difficult to achieve in reality. Certain categories of persons are exempt from paying the premiums. These include children less than 18 years of age whose parents are registered. Membership is open to all residents of Ghana.[1,48,53]

The NHIS, by design was meant to be a truly universal health coverage policy. The mandate of the NHIS is to improve the utilization of healthcare services by all residents of Ghana through the removal of financial barriers to accessing care.[41,46] In addition to the public NHIS, the National Health Insurance Law, Act 650 allows for the operation of private and commercial health insurance schemes subject to regulation by the NHIA. Formally employed people who contribute to the public social security scheme are automatically registered under the NHIS and have their premiums deducted from their contributions.[54,55]

The NHIS offers a generous benefits package with coverage for more than 90% of the health conditions commonly encountered in Ghana. The few exceptions include conditions such as HIV/AIDS and tuberculosis for which the government has established separate disease control programs. Some high-cost medical conditions and procedures such as cancer care, dialysis and orthopedic implants are also not covered under the scheme. The NHIS pays for hospitalization, delivery, and most surgical procedures. Basic vision and dental care are also covered. The scheme pays for generic versions of prescription drugs listed in the Ghana Medicines Drugs List—a list produced by the Ghana National Drugs Program under the auspices of the Ministry of Health of Ghana and based on the WHO list of essential medicines.[51,56] The NHIS pays standardized prices for these drugs and these prices apply nationwide. Members are not required to make co-payments (i.e. additional payments at the point of service). There is no co-insurance required (i.e. members are not required to pay a proportion of cost of services received) and members have no deductibles (i.e. they do not have to pay a minimum amount for services received before the insurance kicks in). There is limited gate-keeping for accessing specialized services though members often require referral from primary care providers to see specialists due to the limited availability of such services.[44,49,54,55]

The NHIS initially operated a fee-for-service payment model under which providers were reimbursed for services provided as line-items. The scheme later switched to a Diagnoses-Related-Group (DRG) payment model for outpatient care. Under this model, providers would be reimbursed a standardized amount for all care provided for a given diagnosis. Standard diagnostic codes derived from the International Classification of Diseases (ICD) system have been published by the NHIA for this purpose. The fee-for-service model was maintained for certain procedures and inpatient care. In Ghana, most healthcare professionals including doctors,

nurses and pharmacists are paid salaries (the government is the largest employer of healthcare workers) and do not bill patients directly for services provided.[49] Healthcare providers submit claims for services dispensed to clients, and these claims are vetted by the NHIA. If approved, the claims are paid from the NHIS fund—a designated government account into which the 2.5% NHIS VAT levy is paid.[42,57]

1.2 Knowledge gaps

The NHIS has been extensively studied since it was established.[47,54,58–62] However, gaps still remain in our understanding of its impact. In this dissertation I set out to describe and contribute to addressing three of these gaps.

Firstly, while there is considerable evidence that the NHIS has improved healthcare access and utilization for the people registered under the scheme (its membership),[54,63] it is not clear that the same effect would be observed if the population was considered in its entirety—i.e. if its effects were assessed without considering the coverage status of individuals. This could be due to a number of reasons which I explore in further depth in chapter two. Most important of these is the fact that even though it is mandated to do so the NHIS does not yet cover everyone in Ghana. By some estimates less than half of the Ghanaian population maintain continuous coverage under the scheme.[64,65] Studies suggest that its membership may not be representative of the wider Ghanaian population, especially in terms of its distribution of socio-economic characteristics.[66,67] Thus, the impact of the policy on its membership may not reflect its overall population-wide impact.

Secondly, few evaluations of the NHIS have looked at its impact on actual health outcomes such as mortality. Most studies examining the impact of the NHIS have looked at its impact

on health system performance measures such as healthcare access and utilization. One of the reasons these health system measures are used to evaluate the impact of health policy is that improvements in them should eventually lead to improvements in population health outcomes such as morbidity and mortality.[68–70] However, this relationship may not always hold for two reasons. In the first place, improvements in access and utilization may occur together with a deterioration in the quality of care provided. This could happen for example, if increases in access to care are not accompanied by improvements in health system capacity and resources, thus leading to an overburdening of health facilities. Additionally, adverse changes in non-health system determinants of health outcomes (such as environmental and nutritional factors) may cancel out gains in health outcomes resulting from improved healthcare access.[71–73] Malnourished children living in poor sanitary conditions may keep getting sick even if their community is provided with a new clinic. Consequently, gains in healthcare utilization and other health service metrics may not necessarily reflect actual improvements in the health status of the population. In order to obtain a holistic understanding of the impact of policy, actual health outcomes must be considered.

The final gap concerns a core principle of the NHIS: equity. Universal health coverage, at its heart, is meant to ensure that all people are able to access healthcare according to their needs irrespective of their social situation or financial means.[46,48] After a decade of implementation, it is not clear that this goal is being achieved by the NHIS. This question becomes especially pertinent when rural dwellers are compared with urban dwellers.[74–76] As mentioned above, the membership of the NHIS has tended to be skewed in favor of urban dwellers, the formally employed and the generally socio-economically advantaged—the same classes of people, who were better-off under the cash-and-carry system.[64,75,77] Further, non-financial factors that

influence utilization of healthcare (such as physical access to health facilities and socio-cultural norms influencing health-seeking behavior) are often distributed to the disadvantage of people of lower socio-economic status (such as rural dwellers).[78,79] Taken together, these factors could lead to a concentration of benefits in those of higher socio-economic status. In such a case, rather than improving equity, the policy may be harmful or indifferent to inequalities in healthcare utilization and outcomes.[80–82]

1.3 Aims and objectives

This dissertation contributes to filling the above-mentioned knowledge gaps by assessing the population-wide effect of the NHIS on healthcare utilization and early childhood mortality, while considering its impact on equity (primarily rural-urban inequalities in these outcomes), as well as the mechanisms by which it affects inequalities in these outcomes. My overall approach to these questions is illustrated in Figure 1.1. It shows the relationships between key variables and how these correspond to my specific objectives.

Throughout this thesis, my primarily interest has been in rural-urban inequalities in health outcomes (illustrated by the thick yellow arrow in the figure below) and how these are influenced by healthcare financing policy. In my quest to understand this relationship, I also examined other pathways which intersect with or intervene in this primary relationship.

First, I explored the relationships between healthcare policy, healthcare service utilization and health outcomes (i.e. between nodes A, B and E in the figure), and how these are influenced by socio-economic characteristics. The findings of this first investigation provided a baseline understanding of the impact of the policy on actual health outcomes (early childhood

mortality), as well as on key intermediate outcomes (illustrated by the green arrows in the figure).

I next considered the relationship between healthcare financing policy and rural-urban inequalities in early childhood mortality (nodes A, D and E in our diagram). These were the relationships I was primarily interested in as I sought to describe and explain how health financing policy has affected equity in health outcomes.

Finally, I explored one of the possible mechanisms underlying the impact of the policy on rural-urban inequalities in health outcomes. I investigated the role of healthcare services utilization as a mediator of rural-urban disparities in health outcomes (i.e. the pathways described by the black arrows). This involved examining the relationships between nodes. D, B and E.

The above investigations were aimed at achieving the following specific objectives:

1. To estimate the effect of the NHIS on healthcare utilization and early childhood mortality considering children born in Ghana between 2003 and 2013
2. To assess the impact of the NHIS policy on levels and trends in rural-urban inequalities in early childhood mortality for children born in Ghana between 1993 and 2013

3. To explore the role of healthcare utilization, specifically skilled attendance, in driving rural-urban disparities in early childhood mortality for children born between 1993 and 2003

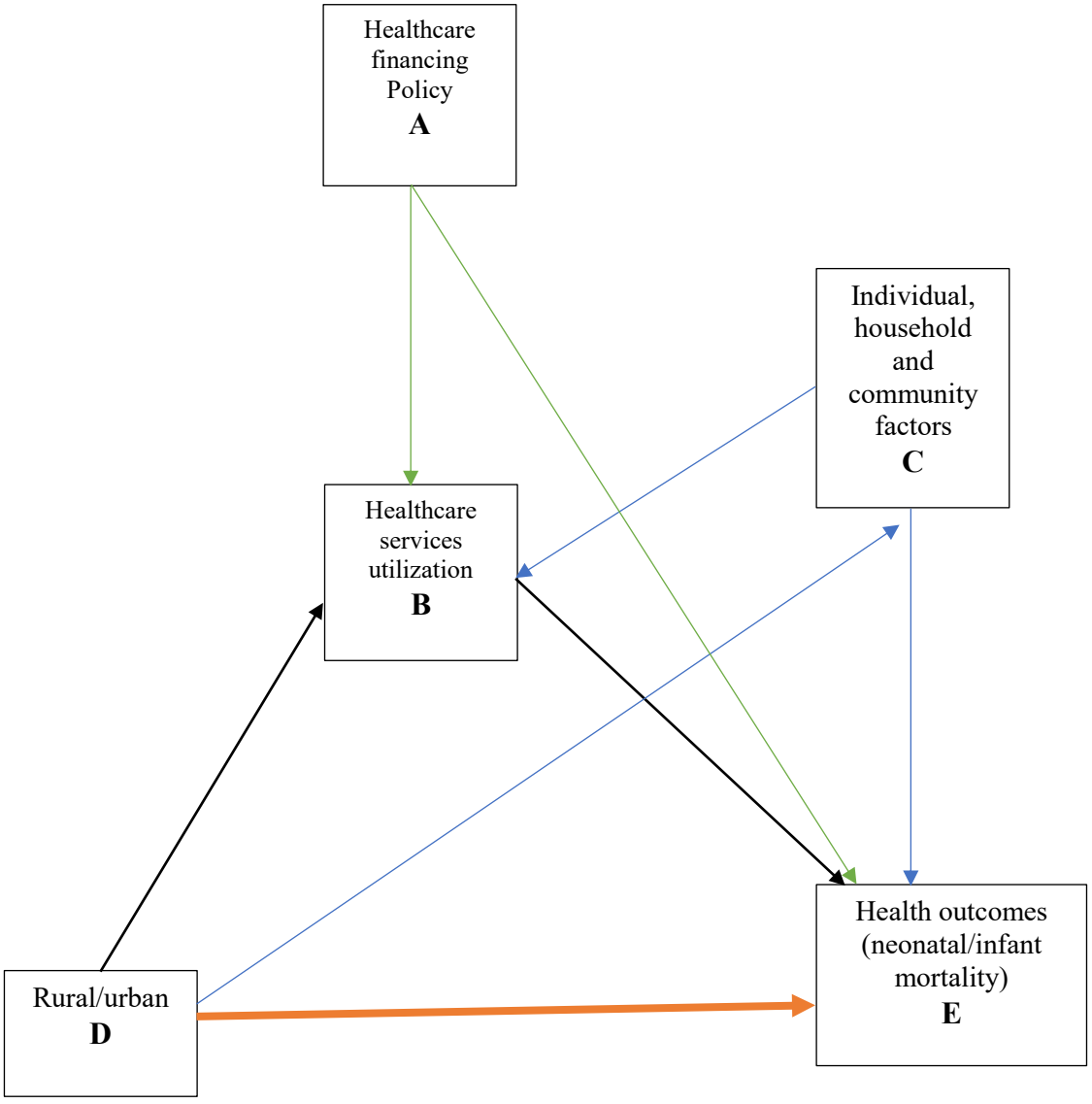


Figure 1-1: Relationships between rural/urban residence and other factors which determine neonatal and infant mortality

1.4 What's new in this work

This work hopefully enriches the existing literature in two important ways. Firstly, it makes a number of important contributions to the literature on the impact of the NHIS and UHC policies in general. The novelty in this case stems firstly from the use of a population-wide perspective, which considers not only the direct effects of the NHIS on its membership, but also indirect effects of the policy on the health system at large. This work also adds to our knowledge of the effects of the policy on actual health outcomes (rather than health system performance measures), as well as on equity in these health outcomes.

On the methodological front, this dissertation makes two important contributions. It provides an example of the application of an interrupted time series analysis to the evaluation of health inequalities. It also applies the 3-way decomposition approach of VanderWeele to the exploration of the mediation of health inequalities using a targeted maximum likelihood estimation approach. In doing so, it helps to expand the range of tools available to the researcher exploring health inequalities.

1.5 Organization of thesis

This rest of this dissertation is organized as follows: In the chapter 2, I give a brief historical and conceptual background to UHC policies in general. I then summarize the current literature on the NHIS and its impact on health outcomes.

In chapter 3, I introduce the data and methods I used in this thesis. In the first part, I describe my main data source, the Demographic and Health Surveys (DHS).[83] Following this, I briefly introduce three study designs and analytical methods I use later in this dissertation: difference-in-

differences analysis,[84,85] interrupted time series analysis,[86,87] and the 3-way decomposition of mediation and interaction effects of VanderWeele.[88]

In chapter 4, I present the first of the three manuscripts which make up this dissertation. It assesses the impact of the NHIS on healthcare utilization and early mortality for the Ghanaian population as a whole, and across socioeconomic categories, using data on children born in Ghana from 1993 to 2013.

Chapter 5, the second of the manuscripts, explores the impact of the NHIS on levels and trends in early childhood mortality, comparing children born in rural and urban areas of Ghana between 1993 and 2013.

The final manuscript, presented in chapter 6, examines the role of healthcare utilization, specifically, skilled attendance at birth, as a driver of rural-urban disparities in early childhood mortality. In it, I explore mediation and interaction as possible mechanisms underlying these relationships and decompose and quantify the contribution of each of these components to the total rural-urban disparity.

In chapter 7, the final chapter, I summarize and conclude on the findings of this thesis.

2 LITERATURE REVIEW

In this chapter, I introduce the key concepts of UHC using historical and current implementations as examples. I then summarize the current literature on the impact of the NHIS on health outcomes in Ghana. I subsequently examine the literature on trends in early childhood mortality in Ghana and also on determinants of rural-urban disparities in early childhood mortality in general.

2.1 Approaches to UHC

While the details of health system financing arrangements differ from country to country, four models representing the predominant approaches to providing universal access to healthcare in developed countries in the 20th century, have emerged. These models are generally referred to as the Bismarck (social insurance), Beveridge (single-payer national health service), National Health Insurance (single-payer national health insurance) and Out of Pocket Payment (market-driven) models.[39,89,90] These approaches may be distinguished under the functions-of-health-systems framework[91,92] by the way they handle resource mobilization, risk-pooling and service provision.

The first modern national health financing system was the Bismarck model first implemented in Germany in the 19th century. This model, also known as the social insurance model, is employment based. Employees have access to "sickness funds" created through payroll deductions, as well as private health insurance plans (for which premiums are paid). These plans cover all employed people and their dependents. In Germany, while the health insurance funds are public entities, actual health provision is done by mostly private institutions. The government regulates prices for both insurers and providers and thus keeps costs contained.

Many insurers in this model are not-for-profit organizations. This model in its strictest sense does not embrace the idea of healthcare as a right. It is focused on providing healthcare in a sustainable manner to those who are able to contribute to financing the healthcare system. This model has been replicated with some variation in France and Korea (both of which have single insurers), Japan (where there are multiple insurers who do not compete with each other for clients), and in the Czech Republic (where, like Germany, there are multiple insurers who compete with each other).[90,93,94]

The Beveridge model was conceptualized by Sir William Beveridge and was first implemented in 1948 as the National Health Service (NHS) of the United Kingdom.[90] The Beveridge model uses a centralized approach to healthcare provision. There is a single national risk pool, a single payer—typically the government—and healthcare funding is mainly generated through general taxation. Services are mostly provided in public facilities by government-employed health workers and are available to everyone. All patients are provided the same level of care and patients are not required to make any out-of-pocket payments. This model is founded on the idea of healthcare as a right. It has been copied in Spain, New Zealand and Cuba.[39,94] One interesting instance of a Beveridge model is the Veterans Health Administration in the United States of America, which provides healthcare for former United States Armed Forces personnel through a network of government-run hospitals funded by tax-payers.[95,96] This system stands in sharp contrast to the employment-based market-driven approach to healthcare that is predominant in the United States of America.[97,98] While the Beveridge model is notable for keeping costs contained, and perhaps coming the closest to providing true universal access to care, it has also been criticized for long patient wait times and overutilization of services by patients.[99,100]

The National Health Insurance Model, on which the Ghanaian NHIS is based is a hybrid of the Beveridge and Bismarck models. It has a single public payer, like the Beveridge mode, but also uses private providers like the Bismarck model.[39,94] This model is notable for reducing administrative overhead and avoiding duplication of services. There are few financial barriers to accessing care though this system is notorious for having long wait times for services--especially specialist services. These delays have sometimes become so severe that they have become political issues rather than just operational matters. This model also suffers from overutilization of health services as well as increased costs as the population ages (due to both increased costs from the higher burden of chronic diseases among the aged and also decreased funding as these aged are mostly retired and not contributing to the public purse).[39,101] While Canada is one of the few developed countries that currently operates such a model, some countries such as Germany and Hungary, whose systems are based on the Beveridge or Bismarck models have adopted more and more elements from other models giving their systems a decidedly hybrid look.[94]

The market-driven out-of-pocket payments model is quite common in low-income contexts such as sub-Saharan Africa, rural areas of South America and China.[24,102] It also applies to the one-in-ten Americans who do not have health insurance.[103] This approach to healthcare financing essentially rejects the idea of healthcare as a right.[97] In this system, access to healthcare is determined by financial means. People who need healthcare have to pay (often upfront) for services provided.[13,104] While its prevalence in poor countries could be attributed to a lack of resources and institutional capacity to implement one of the other three health financing models, its existence in the United States could arguably be attributed to an ideological stance.[13,97] This system has been associated with high levels of disparity in healthcare utilization and outcomes. While this model might be expected to result in reduced healthcare expenditure (from reduced

utilization as well as lower public expenditure), this has not been found to be always the case. Patients, who are unable to access lower-cost primary or preventive care may present with complications which are much more expensive to treat. And since such patients are often unable to afford their treatments, the costs are often borne by the public purse. In addition, sick people who are unable to afford treatment are unable to work and contribute economically.[20,28,39]

2.2 UHC in the developing world

In the 1980s, many developing countries instituted user-fees charged at the point of service, as a way of funding their health systems. Such fees were often needed to make up for funding gaps resulting from economic austerity measures, which had been imposed by international financial institutions as part of "structural adjustment" economic programs.[105,106] User-fees have since been shown to reduce the utilization of essential health services and increase the risk of incurring catastrophic medical costs.[13,107,108]

As the negative effects of user-fees became apparent with time, some of these developing countries switched to other approaches to health system financing. Those countries mostly adopted hybrid systems, which varied considerably in design and scope. Some countries, such as India, Indonesia, the Philippines, and Vietnam, developed programs aimed at improving access to healthcare for specific subpopulations identified as the least able to afford point-of-service costs for healthcare. Other countries such as Vietnam, and the Philippines, opted for systems akin to a national health insurance model—a single-payer system that provides coverage for all citizens.[109,110]

Another way in which countries have differed in their approach to UHC reforms has been the manner of healthcare service delivery itself. Some countries have established centralized

administrative and regulatory mechanisms for ensuring healthcare delivery. In most countries, people may access services from both public and private providers, though to varying extents. Countries vary in the extent of private participation in healthcare provision. In many developing countries, public providers remain the most important component of the health system and often receive supplementary funding through budget allocations independent of the general health financing pipeline.[91,111]

In sub-Saharan Africa a broad range of approaches to healthcare financing and provision have been used over the years.[39,102,109] Many former colonies inherited health systems that were designed to cater primarily to the needs of their colonial masters. At independence many countries in sub-Saharan Africa sought to provide free healthcare to their populaces. Over time, some of these countries found the free healthcare model unsustainable and transitioned to other healthcare financing systems.[112] Many countries in the region have embraced the idea of UHC but are at varying stages of implementation of the idea. The range of UHC policies in the region is illustrated by the four countries whose approaches to UHC are described briefly in table 2.1.

2.3 Monitoring and evaluating UHC reform programs

Continuous monitoring and periodic evaluation are important tools for ensuring the successful implementation of UHC policies. A number of frameworks have been devised to guide such monitoring efforts.[113,114] The WHO and the World Bank have together developed a global UHC monitoring framework that tracks population coverage of essential services, financial protection against catastrophic out of pocket expenditure (OOPE), and stratifies these outcomes by wealth, place of residence and sex.

This framework has been summarized conceptually as the WHO UHC cube, which has three perpendicular axes representing the three goals of UHC: i.e. extending healthcare to the non-covered, reducing cost-sharing and OOPE, and improving the range and quality of healthcare services provided. The progress of UHC in any country could be measured along these axes, and the resulting cube would then represent the overall progress the country has made towards UHC.[115]

Table 2-1: Brief descriptions of selected UHC policies in sub-Saharan Africa

Country	UHC policy context
Tunisia	There is a two-tiered system with government-run free healthcare provided through public health centers and funded by general revenues as the first tier. There is growing private-sector participation in health service provision. The second tier is health insurance.[105–107] funded through employee contributions. Problems of equity still exist.
Ethiopia	No official policy on UHC has been defined. No specific goals for UHC set. Multiple initiatives being implemented to improve access to primary health care. Healthcare coverage remains poor for a large part of the population despite significant progress being made in several healthcare indicators[108,109]
Tanzania	A free healthcare policy was adopted after independence in 1961. User fees were reintroduced in the 1990s with exemptions for the poor. A National Health Insurance Fund for public sector employees was established in 1999. A Community Health Fund was established in 2001 to cover workers in informal sector. A 10-year Primary Health Care Development Plan was implemented from 2007 to 2017. A National Health financing policy is currently being developed[110]
South Africa	There are two parallel health systems. Private voluntary health insurance covers about 17% of population. A majority of population is served by public tax-funded healthcare services. A policy was initiated in 2011 targeting the achievement of UHC over a 15-year period. The policy plans to establish a tax-funded National Health Insurance Fund which would entitle everyone to access comprehensive health services.[111,112]

Within this framework, there is a strong emphasis on equity and so measures, as much as possible are disaggregated by socio-economic characteristics such as income, wealth, education, sex and place of residence.[113,115]

In most countries, there is no stand-alone monitoring mechanism for UHC—the progress of UHC is tracked in the same manner as other measures of health system performance. One of the challenges encountered in any attempt to evaluate UHC policies is a lack of reliable, accurate data for program evaluation. Many countries rely on periodic sample surveys to provide such data. In particular, the Demographic and Health Surveys (DHS)[83,116] have been a key data source for evaluating UHC programs. Surveys such as the DHS are however relatively infrequent and do not provide data on some measures which are important for evaluating UHC. It especially lacks measures of health expenditure and health system performance. Other sources include annual and other periodic reports prepared as part of regular health system management activities.

2.4 Challenges of UHC in low-income countries.

Low- and middle-income countries setting out to implement UHC reforms face several hurdles. Perhaps the most commonly encountered is an inability to mobilize adequate revenue to fund such reforms. While UHC reforms have been shown to save on total health expenditure, they generally require that government expenditure on health is increased—especially at the outset. Many low-income countries struggle to achieve this.[117–119] Low-income countries have adopted many different approaches to mobilize the revenue needed to fund UHC programs. Some countries including India, Indonesia, the Philippines, and Vietnam have levied general taxes, or instituted specially earmarked taxes to fund healthcare costs.

Some countries have supplemented general taxes with household premiums (as has been the case with the NHIS in Ghana).[28,120]

For many developing countries, the largely informal nature of their economies hampers the collection of taxes and premiums. Consequently, these approaches to revenue mobilization have had varied success. Some countries have opted to simply absorb or subsidize costs at the point of service in public healthcare institutions using allocations from the general health budget.[31,53,121]

One consequence of the difficulties low- and middle-income countries face in mobilizing revenue is that their health system reform programs often entail redistributing healthcare costs rather than increasing investment in healthcare. The overall public expenditure purse typically remains the same size. Consequently, these reform efforts often necessitate trade-offs which may leave some people worse off in the end. For example, as more money is put into improving access to healthcare, other health-related expenditure such as health promotion efforts, may suffer.[31,53,121] Another by-product of the difficulties many low- and middle-income countries face in raising revenue is that external donor support continues to be an important source of funding for healthcare.[20,39,109,122]

Another commonly encountered barrier to the achievement of the goals of UHC in low- and middle-income countries is a poor availability and distribution of healthcare resources. In many such countries, and especially in sub-Saharan Africa, healthcare services are not geographically accessible for many people. Many of these countries suffer chronic and severe shortages of healthcare personnel and resources, often made worse by inequalities in the distribution of the few resources they do have available.[123–125] Even South Africa, one of the

richest countries in Africa struggles to provide adequate healthcare services for all its residents, as evidenced by its failure to meet the WHO Service Availability and Readiness Benchmark for inpatient beds in 2011.[18,126,127] Being able to afford healthcare means little if the healthcare services are not available in the first place, or are of such poor quality as to be of little benefit.

One of the concerns with UHC reform programs in general is that they sometimes have the unintended consequence of causing a deterioration in the quality of healthcare services available. This happens when the demand for healthcare services outstrips supply and the health system is strained beyond capacity. Even high-income countries providing universal healthcare must sometimes contend with long wait times when too many patients require a particular service. This situation is seen more often, and to a greater degree, in low- and middle-income countries implementing UHC programs. As they often lack the resources to expand healthcare service availability in tandem with the resulting increasing demand, their already strained healthcare systems may be stretched to near breaking point.[114,118,128,129]

Again, while UHC reforms are meant to improve equity in healthcare access and utilization, they sometimes inadvertently have the opposite effect. When such policies target specific classes of people (such as the formally employed), they may end up widening the gap in healthcare access between those covered and those left out, instead of narrowing it. In effect, the benefits enjoyed by the former make the latter relatively worse off.[125,130,131] The WHO warned of this phenomenon in its World Health Report of 2010.[24] One implication of this is that any comprehensive evaluation of a UHC policy must consider its impact on the entire population and address questions of equity.

2.5 The impact of the NHIS

In this section, I briefly discuss what is known about the impact of the NHIS on healthcare utilization and financing—i.e. how it has performed relative to its core mandate. I further explore its wider health system impact, including its impact on equity in health outcomes.

2.5.1 Insurance coverage

The NHIS is mandated to increase healthcare access and provide protection from catastrophic medical costs for all residents of Ghana—a charge whose discharge requires that it covers as many Ghanaians as possible. While reliable measures of coverage at the national level are not readily available, evidence from localized studies suggests that coverage rates have been low—generally below 50%.[44,64,75,132–134]

One of the main reasons often given for these low coverage rates is that the annual premiums charged to renew membership of the scheme are unaffordable.[64,77] The system of exemptions meant to ameliorate this situation for those in extreme poverty has not worked as expected due in part to the practical difficulties involved in identifying and proving need.[134–136] The notion of poverty being the main driver of loss of coverage has however been disputed by the findings of Kusi (2015), which suggest that more than two-thirds of households surveyed should be able to afford their NHIS premiums.[64,137,138] Two other explanations which have been suggested as contributing to the low coverage rates are a lack of trust in the NHIS as an institution, and both real and perceived problems with the quality of healthcare services provided to patients under the scheme.[48,139]

Among the quality-of-care issues commonly raised are long wait times, limited patient choice, lack of privacy, and unfriendly providers.[140–142] In truth, there is some evidence that increased

utilization of healthcare services resulting following the implementation of the NHIS may be overburdening the healthcare system and this may be translating into poorer client services. This situation has likely been worsened by the frequent delays in reimbursement of providers for services.[142–145]

2.5.2 Healthcare utilization

The NHIS has been shown to have improved access to, and utilization of, health services for those covered under the policy. [51,136] Membership of the NHIS has been found to be associated with increased use of antenatal care, delivery in a health facility and skilled attendance at birth. When ill, those covered have been found to be more likely to seek medical care rather than resort to traditional/herbal remedies or self-medication—a practice much more common among the uninsured. [59,146,147] This effect has been found to persist even after adjusting for socio-economic factors such as wealth and education, and accounting for self-selection into enrollment.[63,148]

The rich-poor divide in healthcare access that existed in the time of "cash-and-carry" may have been replaced by an insured-uninsured equivalent in the NHIS era. Just as the poor used to do in the era of "cash-and-carry", the uninsured in the era of the NHIS tend to visit health facilities only for the most critical health conditions. [59,146,147] Such a divide may have developed because of differences in the capacity of people of different socio-economic status to take advantage of the benefits offered under the NHIS—a situation attributable to, among other things, differences in levels of education and access to transportation.[64,77,112 142,149,150]

The NHIS has also influenced healthcare practice. Providers have been found to offer more care (diagnostic testing, prescriptions and procedures) to insured compared to uninsured patients.[151]

It is not clear that such extra care is always motivated by the expectation of improved health outcomes rather than commercial considerations.[55]

2.5.3 Impact on health system financing

The advent of the NHIS drastically changed health system financing in Ghana. It caused a shift in the distribution of the burden of financing between government and households, with a considerable reduction in the share of overall medical expenditure borne by households.[45,152] The NHIS contributed to a decrease in the contribution of private out-of-pocket expenditure (OOPE) to overall health funding from 80% in 2003 to about 66% in 2013.[42,131,153] Government's share of total health expenditure increased from 51% in 2003, to 59% in 2009. Of the 5% of Ghana's GDP spent on healthcare services in 2013, the NHIS alone contributed as much as 40% via the 2.5% NHIS VAT levy.[48,154]

One of the goals of UHC reforms such as the NHIS is the mitigation of OOPE and catastrophic health expenditure (CHE).[13,118] There is a lot of evidence suggesting that UHC reforms in developing countries decrease the proportion of health costs paid out-of-pocket. In countries like Indonesia, Rwanda, and Vietnam, OOPE was found to have decreased by between three and six percentage points after the implementation of UHC reforms. [155–159] Despite this, the risk of catastrophic household medical expenditure has not been eliminated in most cases, as household medical expenditure remains higher than the levels recommended by the WHO.[155–159] On this issue, the evidence on the impact of the NHIS is mixed. While some studies have found that the NHIS has reduced OOPE, others have found that this effect, disappears once selection into enrollment is taken into account.[45,61,63,160]

The increasing costs increasing share of overall medical expenditure borne by the NHIS, in the absence of commensurate increases in revenues, has challenged the smooth operation of the scheme.[1,161] One of the manifestations of this has been frequent delays (sometimes for several months) in reimbursing providers for services provided —a situation worsened by frequent delays in transferring the revenue from the NHIS levy out of the general tax pool to the NHIA.[142] The NHIA has responded to these challenges with several initiatives to improve efficiency and reduce waste and fraud. In this vein, it has experimented with different provider-payment systems including a diagnosis-related-group system and a capitation pre-payment model (currently under pilot).[48]

2.6 Trends in early childhood mortality

Child health outcomes in Ghana remain poor across sub-Saharan Africa despite some improvement over the past three decades.[162,163] While the situation in Ghana is arguably better than others in the region, there is still much room for improvement. Even by the most optimistic estimates, more than 80 of every 1000 children born do not reach their fifth birthday.[164,165] This situation is especially concerning because the majority of these deaths are from preventable causes such as infections and malnutrition. There is evidence though, that this situation is on the mend as child mortality has shown a steady pattern of decline over the past 20 years.[164]

It appears however, that these gains have not been evenly distributed across all strata of the population of Ghana. Rural dwellers have tended to suffer worse outcomes compared to their urban counterparts. Data from the past 10 years shows that rural children are almost twice as like to die before their first birthday and about 25% more likely to die before their fifth. Evidence from the Ghana Demographic and Health Survey of 2014 showed that only 83% of pregnant rural women attend the recommended minimum of 4 antenatal visits compared to 97%

of their urban counterparts. Similarly, while 90% of urban newborns were delivered by skilled birth attendants, only 60% of rural babies enjoyed that privilege.[164,166–170] These disparities have persisted even in the face of policy interventions to close gaps in access to, and affordability of access to health services.

2.7 Determinants of rural-urban disparities in early child health outcomes

Child health outcomes are known to be influenced by both individual and contextual factors. Context as used here, refers to those characteristics of communities (rural or urban) that tend to be place-specific and which may vary little over the life course of an individual. Relevant factors in this regard include healthcare system[171,172] characteristics (such as the availability, quality and responsiveness of healthcare services),[141,173] socio-cultural factors (including norms around health seeking behaviour, gender roles, women's empowerment, traditional health practices,[172,174,175] as well as demographic factors such as fertility and population density and growth). The individual characteristics most studied in the literature are education and socio-economic status.[169,170,173] There is a considerable body of work showing that these factors, both contextual and individual, are associated with child mortality outcomes and also unevenly distributed between rural and urban areas. This makes them likely contributors to rural-urban disparities in child mortality.[167,173,176]

The gains in child health outcomes in Ghana mentioned above have been attributed in part to improvements in health system factors (such as the availability and utilization of healthcare services),[127] and positive trends in the levels and distribution of socio-economic characteristics, (such as educational attainment and income).[175] The Government of Ghana has also been praised for its interventions to increase the availability of healthcare services and remove cost barriers to accessing healthcare.[59,177]

One widely-used theory based on the roles of individual and contextual factors in determining health outcomes is the three-delays model (for explaining poor obstetric outcomes).[178] It attributes adverse maternal and child health outcomes to delays in seeking, reaching and receiving care. Delays in seeking care reflect health-seeking behaviour, which is influenced by individual characteristics such as education as well as social norms such as requirements for spousal consent to seek care. Delays in reaching care may be largely attributed to contextual variables such as ease and cost of transportation and distance to MCH services. The third delay, receiving care gives a measure of healthcare system service quality and responsiveness, which in turn depends on the availability of resources (including human), infrastructure and organizational characteristics.[162,179,180]

2.8 Policies relevant to child health outcomes in Ghana

The Government of Ghana's approach to improving child health outcomes in Ghana has emphasized improving access to healthcare, especially in the rural areas. This, in practice, has meant mainly targeting improvements in the availability, affordability, and to some extent, quality of healthcare services.[127,181] Two policies born of this approach are the Community Health Planning and Services (CHPS) and the Free Maternal Healthcare policy (FMH).

CHPS is a community-based health access model that was implemented in Ghana in 2005 and meant to address gaps in access to primary care and basic obstetric care.[182] It embeds community health workers in communities to provide access to preventive and basic healthcare services directly in communities. The FMH was instituted in 2008 as a component under the NHIS.[141] It removed the NHIS requirement for registration and premium payment for pregnancy, delivery, postpartum, and neonatal care services. It thus effectively made maternal

and neonatal care free in Ghana.[57,177] These policies have been shown to improve access to, and utilization of maternal and child health services in Ghana.[170,183–185]

3 METHODS AND DATA

In this chapter, I discuss the data sources I used in the manuscripts in this dissertation. I also briefly introduce the methods I use in this thesis—specifically difference-in-differences analysis, interrupted time series analysis, and the VanderWeele 3-way decomposition of mediation and interaction effects.

3.1 Data

In this thesis, I used data from the Demographic and Health Surveys (DHS).[116,186] The DHS are repeated cross-sectional survey series conducted in several countries to gather information on

Table 3-1: DHS datasets used in this study (by country and survey year)

Country	Years
Ghana	1993, 1998, 2003, 2008, 2011, 2014
Burkina Faso	1993, 1998, 2003, 2010
Bangladesh	1994, 1997, 2000, 2004, 2007, 2011, 2014
Zimbabwe	1994, 1999, 2005, 2010, 2015
Malawi	2000, 2004, 2010, 2016
Uganda	1995, 2001, 2006, 2011, 2016
Cameroun	1998, 2004, 2011
Lesotho	2004, 2009, 2014
Egypt	1995, 2000, 2005, 2008, 2014

Note:
Survey years represent year in which survey was reported. Actual years of interview may differ.
All DHS datasets downloaded with permission from https://www.idhsdata.org/idhs/

reproductive, maternal/child health issues, demographic trends (including fertility, marriage and contraception), as well as other country-specific topics. The surveys use similar methodologies even though the details of implementation are determined by each country. In this thesis, I used

the International Public Use Microdata Demographic and Health Survey versions of the DHS datasets (IPUMS-DHS).[187] For analyses from Ghana, I used data from the surveys for 1993, 1998, 2003, 2008, and 2013. The details of the other survey datasets I used are provided in Table 3.1.

Even though the DHS surveys are organized according to common guidelines (and include a common core set of questions), the exact phrasing of these questions and the coding of responses sometimes differ from one country to the next (and even between surveys from the same country), since the actual implementation of the surveys is left to each country's discretion.[83,116] This makes the analysis of multi-survey data challenging. The IPUMS-DHS[187] datasets were created to mitigate this problem. These datasets were derived by recoding raw DHS datasets to generate variables, which have as much as possible been made consistent in definition and coding across all surveys in the series. This greatly facilitates the comparison of variables across countries and survey-years.

Another issue one has to deal with when analyzing data from multiple DHS surveys is the fact that the underlying survey sampling strategies often differ from survey to survey, and from country to country. To enable the estimation of accurate prevalence measures, sample weights are provided for individuals, households, and sometimes for special strata within the data (such as subsamples selected for anthropometric examinations).[116] In these analyses, I applied these weights as inverse probability weights to account for selection into the surveys, so I could pool data from multiple surveys for my analyses.[188] I adjusted these weights for the sampling fraction of the female population in each country for each survey year. The resulting weights are given as

Equation: 1: $W_{ict} = \frac{n_{ct}}{P_{ct}} * w_i$

Where

n_{ct} is the number of women aged 15 – 45 years interviewed in country c, in survey year t,

P_{ct} is the population of females aged 15 – 45 years in country *c,* in survey year *t.*

w_i is the individual sample weight for each woman *i* interviewed.

I used DHS birth records data, which are obtained by interviewing all women of child-bearing age, in each sampled household, about all children they had ever had. For each child the survey obtained information on date of birth, demographic characteristics and other family information, and whether the child is currently alive. In addition, for a subset of children born within 5 years of each survey (designated the child records dataset), information on pre- and post-natal care for mother and child was also obtained. Both the DHS and IPUMS-DHS datasets are publicly available, subject to registration.

3.1.1 Limitations of DHS data

The use of DHS data introduces several important limitations that must be considered when interpreting the results of any analysis. One important limitation results from the fact that the DHS birth records dataset is not well suited to distinguishing between stillbirths and early neonatal deaths.[171] A recently-published study purported to use DHS data to examine stillbirths as an outcome, by leveraging information on the reproductive and contraceptive use patterns of respondents.[172] However, there is evidence that while aggregate estimates obtained thus may be fairly accurate, individual-level data cannot be relied on.[173,174] The underlying reasons for the unreliability of DHS survey data in this instance are at least partly cultural in origin. In some African cultural traditions, for example, there is a commonly-held belief that children are visitors from a spiritual world who may return to that world at any time within the first week of birth.[175] Needless to say, such beliefs would affect the perception and reporting of such deaths.

The potential misclassification of stillbirths and early neonatal deaths could affect the results of our analyses, especially if these outcomes occur differentially between urban and rural areas. If such misclassification acts to increase the apparent occurrence of neonatal mortality in rural areas, for example, the impact of any intervention, which changes the occurrence of early neonatal deaths in rural areas relative to urban areas would appear attenuated. In a similar fashion, we would tend to detect a smaller effect on early childhood mortality among lower socio-economic groups compared to higher socio-economic groups due to differences. This is an important consideration in this work as one of its primary aims is to explore the effect of policy interventions on equity.

The study designs we use in the first two manuscripts (difference-in-differences and interrupted time series) have the advantage that the estimates of effect they yield should be unbiased if the degree of misclassification remains constant over time and across groups.

Understanding patterns of stillbirth would also be important for explaining the impact of interventions that improve the stillbirth rate by improving intrapartum care. Such improvements would theoretically result in the live birth of some children who may not have survived delivery without such intervention. Such children tend to have higher mortality rates in early childhood, partly resulting from underlying pregnancy complications that would have resulted in them being stillborn and also from late complications of the intrapartum interventions required to save them.[176–179] The increased mortality among this high-risk group would tend to water down any positive impact of the intervention on early childhood mortality.

3.2 Methods

In this section, I briefly introduce the three analytical methods I use in this thesis. Further detail is provided in the chapters in which these methods are applied.

3.2.1 Difference-in-differences analyses

In the first manuscript of this thesis, I used difference-in-differences (DD) analysis[83,180,181] to estimate the effect of the NHIS policy on healthcare utilization and early childhood mortality. DD is an increasingly popular method for estimating the causal impact of interventions applied to populations when data on non-intervention populations are available. The timing of the intervention creates pre-and post-intervention time periods and difference-in-differences compares outcomes between intervention and non-intervention groups, between the pre- and post-intervention time periods. This approach may also be used where the intervention is applied to multiple populations at the same or differing times. In such cases, there would be multiple treated groups.

If the assumptions underlying the DD approach to evaluating policy outcomes can be held to be valid, then the method produces a valid estimate of the average effect of the treatment on the treated (ATT).[83,182] In theory, the DD approach can account for time-stable confounding, both measured and unmeasured. As discussed below, the assumptions underlying DD analysis are rather strong and untestable. Other approaches have been used to try to relax these assumptions. For example, where no suitable control group could be found, synthetic control groups have been used in some cases.[183,184]

The identification of causal effect in difference-in-differences analyses requires that the so-called parallel trends assumption holds. This assumption holds if the difference in the outcome between

intervention and control groups would have remained constant over time in the absence of the intervention. The parallel trends assumption cannot be verified as it requires knowledge of the counterfactual outcome trends for each group in the absence of the intervention. In lieu of such verification, the commonly-used approach is to examine trends in the outcome across groups for parallelism in the pre-intervention period. If found to be parallel, it is then assumed that, in the absence of the intervention, the pre-intervention pattern of outcomes across groups would continue into the post-intervention period and the groups are deemed to be good counterfactuals for each other.[85,189,191,192]

This assumption is typically checked in two ways: 1) graphically by inspecting plots of outcome trends for each group in the pre-intervention period, and/or 2) by modelling and testing for heterogeneity of outcome trends across groups in the pre-intervention period.[189,192]

Absent any obvious violation of the parallel trends assumption, the DD estimate of the causal mean difference in the outcome attributable to the intervention would be

Equation: 2: $E(Y \mid X = 1) - E(Y \mid X = 0) = [E(Y \mid X = 1, T = 1) - E(Y \mid X = 1, T = 0)] - [E(Y \mid X = 0, T = 1) - E(Y|X = 0, T = 0)]$

Where:
Y = outcome
X = intervention group (1 = intervention group, 0 = control group)
T = time period (0 = pre-intervention, 1 = post-intervention)
$E(Y|X = x, T = t)$ = mean outcome for group *x*, in time period *t*

The parameters in the estimator above may be obtained from fitting linear models to the data with group and time period as covariates and allowing an interaction between group and time period.

In order to account for secular trends in the outcome, time trends in the outcome may be modeled by including linear, flexible or fixed-effects terms for time in the regression equation. Fixed-effects terms for group may also be included where there are multiple intervention and control groups, to account for time-invariant between-groups differences in outcome trends.[193,194]

In estimating standard errors for our effect estimates, we must account for possible correlation between our model errors resulting from clustering. Various approaches have been proposed to handle this, among them the use of fixed-effects terms for group, the estimation of cluster-robust standard errors and bootstrapping.[195–197]

3.2.2 Interrupted time series analysis

In the second manuscript, I used an interrupted time series (ITS) approach[85] to compare rural and urban levels and trends in early childhood mortality, and examine how these were affected by the advent of the NHIS. This method allows for the causal evaluation of interventions which are applied to an entire population at the same time. It is also particularly well-suited to exploring changes in trends and levels of the outcomes both within and across groups. In this thesis, the use of ITS enables outcomes to be compared between groups over time. This gives a more detailed understanding of the patterns of change in outcomes over the study period compared to other analytic methods which provide estimates of average effect over the entire study period.[84,192]

The selection of a control group whose experience can serve as a reasonable approximation for the counterfactual outcome for the intervention group is perhaps the key challenge encountered in all causal inference.[199,200] Causal evaluation methods may be differentiated primarily on their approaches to finding a suitable counterfactual. In ITS, the pre-intervention experience of the intervention group is used to generate the counterfactual for the post-intervention experience of

the same intervention group, and thus, no external control group is required. The interrupted time series study design compares the predicted post-intervention trend in the outcome to the observed post-intervention trend in the outcome—essentially, using the predicted post-intervention trends as counterfactuals for the observed trends. Thus, this method requires that pre-intervention trends are correctly modelled so that accurate predictions of post-intervention trends are made.[201–203]

The identification of effect in this approach requires the absence of unmeasured time-varying confounding as well as time varying effect modification of the outcome by other factors. It essentially requires that all other factors which affect the outcome remain unchanged over the period. In practice, this means that the underlying trends in the outcome due to these other factors progress much slower that changes due to the intervention being evaluated.[87,202,204,205] In this thesis, I apply this technique to examine the effect of the NHIS policy on disparities in childhood mortality. In doing so, I assume that the factors that drive childhood mortality change at a much slower rate compared to the change induced by the policy. As the policy in this case was implemented over a few months, this assumption could be considered quite reasonable.

While typically used in situations in which no external control group exists, the basic ITS design, may be extended with the inclusion of an external control group. This allows the method to account for the influence of secular trends affecting the outcome as these could be expected to affect both the intervention and external control groups equally.[206] When used this way, the ITS method is similar to a difference-in-differences approach except that, while the difference-in-differences method seeks to compare the mean differences in outcome between groups in the pre- and post-intervention periods, the ITS fits a functional form to the trends in the outcome and

thus allows inferences not just on average effects but also on changes in trends (i.e. levels and slopes) in the outcome.[198,201,202] In this particular instance, since I was mainly interested in changes in rural-urban disparities in early childhood mortality outcomes, I used the ITS approach to compare trends in these outcomes between rural and urban dwellers. In doing this, I considered the outcome trends among rural dwellers as counterfactuals for the outcome trends among urban dwellers.

Interrupted time series analysis is a subset of time series analysis and thus requires time series data (i.e. data made up of multiple time-ordered observations on each unit of observation over a period of time). These data have peculiar properties, which must be accounted for in analyzing them. In order to be able to make valid post-intervention outcome predictions based on the pre-intervention time series, issues of stationarity, autocorrelation, seasonality and trends in the data must be assessed and dealt with. In practice, ITS analysis typically begins with a visual examination of trends in the data and the evaluation of the data for the afore-mentioned issues. These, if present, are handled in a similar manner to traditional time series analysis. For example, if the data is found to be serially correlated, autoregression and moving average models (ARIMA or ARIMAX models), or alternatively, linear regression models with autoregressive terms, may be fitted.[87,201,207]

The basic ITS model form (Equation 3) includes a linear term for time, an indicator of being in the post-intervention periods, and a term for the interaction between time and the indicator of being in the post-intervention period. When extended to include an external control group (Equation 4), additional terms for indicators of group membership (i.e. intervention or control),

interactions between group, time and the pre-post indicator, and a triple interaction term involving all three are needed.[87,201]

Equation: 3: $Y = \beta_o + \beta_1 time + \beta_2 post + \beta_3 (time * post) + \gamma C + \epsilon$

Equation: 4: $Y = \beta_o + \beta_1 time + \beta_2 post + \beta_3 group + \beta_4 (time * post) + \beta_5 (time * group) + \beta_6 (group * post) + \beta_7 (time * post * group) + \gamma C + \epsilon$

Where: C is a vector of covariates with γ as the corresponding vector of coefficients

The coefficient for time represents the slope of the pre-intervention trend in the outcome, the coefficient for post represents the change in level going from the pre-intervention to post-intervention period, and the coefficient for group represents the baseline group differences in outcome levels. The coefficient for the interaction between time and post represents the change in slope of the outcome trend between the pre- and post-intervention trend (for the multi-group ITS, it is the change in slope for the reference group). The coefficient of the group*time interaction term represents the pre-intervention difference in the slope of the trend in the outcome between groups. The coefficient for the group*post interaction term represents the difference in the pre-post change in outcome levels between groups. The coefficient of the triple interaction represents the between-group difference in change in slope going from the pre- to post-intervention period.

This basic ITS model specification may be modified with additional terms representing multiple periods, multiple groups or even multiple interventions. Flexible terms for time (such as polynomials and cubic splines) may be added to account for non-linear trends and improve the fit of the model, though this may be at the cost of interpretability.[202]

One important thing to note is that, in order to make valid inferences or to test hypotheses from the ITS model, the model form must be specified a-priori and not be informed by the data.[87,203]

3.2.3 General approach to mediation analysis and the VanderWeele 3-way decomposition

Mediation analysis has become increasing popular as a way of elucidating the mechanisms underlying the effect of an exposure on an outcome in the presence of a third variable which lies on the causal pathway between exposure and outcome. This third variable may be an intermediate on the mechanistic pathway between the exposure and outcome (i.e. act as a mediator) or it may act in concert with the exposure to produce either multiplicative or additive interaction effects, or both. Traditionally, mediation analysis has sought to disaggregate the effect of an exposure on an outcome into—an effect observed on pathways that involve the mediator (mediated effect or indirect effect) and an effect observed on pathways that exclude the mediator (direct effect).[208–210]

In the 1980s, Baron and Kenny developed what could be referred to as the traditional approach to mediation analysis. This took the form of either a qualitative or quantitative assessment of mediation effects. The qualitative approach seeks to establish whether the candidate variable is a full or partial mediator, if at all. This was essentially done by adding the said variable to a regression model and checking for the magnitude of change in the regression estimates from the model.[211,212]

The quantitative approach uses one of what have been termed the difference and product methods. The difference method involves comparing estimates of effects from regression models excluding the mediator to those including the mediator. The difference method is applicable in situations in which there is no association between exposure and confounders of the mediator-

outcome relationship as well as no interaction between exposure and mediator. Here, two regression models are run. The first regresses the outcome on exposure, exposure-outcome confounders, and mediator-outcome confounders. In the second, the mediator is added to the first model. The mediation effect is the difference in the estimates of exposure effect between these two models, and the proportion of effect mediated is given by the ratio of this mediated effect to the total effect.[210,211,213]

If there is exposure-mediator interaction but no association between exposure and mediator-outcome confounders, the product method may be used. This fits a model for the outcome with exposure, mediator, mediator-outcome and exposure-outcome confounders, as well as an interaction between exposure and mediator. The mediation effect (with mediator set to baseline) is given by the product of the coefficient of the exposure term from this model and that from a model of the exposure-mediator relationship.[210,211,213]

3.2.3.1 Causal mediation

Causal mediation refers to a suite of approaches, which extend traditional mediation analysis to allow valid causal inference to be made about mediated relationships. The identification of causal mediation effects requires that certain assumptions hold valid. In addition to the general requirements for valid causal estimation (such as consistency, positivity, no interference and well-defined exposures), four other assumption may apply to causal estimation depending on the approach used. These are:

1. No residual exposure-outcome confounding conditional on measured confounders.
2. No residual mediator-outcome confounding conditional on measured confounders
3. No exposure mediator confounding given measured confounders

4. No exposure-mediator confounders affected by exposure

If the 4th assumption holds and there is no exposure mediator interaction, then the difference method may be used. If it holds and there is also exposure mediator interaction, then the product method may be used. If in addition to the presence of exposure-mediator interaction, exposure is also correlated with mediator-outcome confounders, then neither difference nor product method provides valid estimates.[210,213–215] In such cases, several generalized approaches have been proposed for the estimation of valid mediation effects. These include the use of inverse probability weighting, sequential g-estimation and the targeted maximum likelihood estimation method.[213]

Two kinds of causal mediation measures are typically estimated—controlled and natural effects. Controlled direct effects (CDE) are the effects obtained when the mediator is set to the same level for everyone in the population. They could be thought of as representing the direct effect of an exposure that does not act via the mediator (given that the mediator is at a given level). This could be estimated on the risk difference scale as

Equation: 5: $CDE = (Y|X = x, M = m) - (Y|X = x^*, M = m)$

For the effect of an exposure X (comparing X = x and X = x^*) and fixing the mediator M to a level m. If there is exposure-mediator interaction, then the CDE would be different depending on the level at which M is fixed. Thus, there could be potentially as many CDEs as levels of the mediator for any given exposure contrast.

Natural direct effects (NDE) on the other hand are obtained by setting the mediator to the level it would be at if exposure were assigned to be at some reference level. On the difference scale:

Equation: 6: $NDE = (Y_{xM_{x^*}} - Y_{x^*M_{x^*}})$

Where $Y_{xM_{x^*}}$ represents the value of Y when X is set to *x* while holding M at the level it would have naturally been if X had been set to x^*.

This definition involves a counterfactual and is thus not identified in empirical data. Pearl (2001)[216] however showed that the average natural direct effect could be estimated from empirical data given that that assumptions 1-4 hold. In that case, the NDE could be estimated from data as

Equation: 7: $\sum_m (E(Y_{xm}|C) - E(Y_{x^*m}|C))P(M_{x^*} = m|C)$

A natural indirect effect (NIE) may also be defined on the risk difference scale as:

Equation: 8: $\sum_m (E(Y_{x^*m}|C)(P(M_x = m|C) - P(M_{x^*} = m|C))$

The estimate of the natural direct effect may thus be seen to be a weighted average of the causal controlled direct effects for each level of the mediator with the probability of M = *m*, fixing X to x^* as weights. The natural indirect effect may in turn be thought of as the product of the effect of exposure on the mediator and the level of the outcome holding exposure at its reference value, averaged across all levels of the mediator.[210,213–215]

An interesting property of natural effects is that the total effect of an exposure decomposes additively into its corresponding natural direct and natural indirect effects. In the absence of exposure-mediator interaction, the natural and controlled direct effects would be the same, however, when such interaction is present, each level of the mediator potentially has its own controlled direct effect. In the same situation, we still obtain only one natural direct effect.[210,213–215]

There is some controversy as to the interpretability and relative importance of these measures of mediation. It has been suggested that natural effects should be considered descriptive whiles controlled direct effects are thought of as prescriptive.[217,218] The controlled direct effect, by holding the mediator constant in the population mimics a population-wide intervention and thus has been touted as more policy-relevant by some researchers. Natural effects on the other hand are often interpreted in an attributional sense. They assess the degree to which total effects are due to the natural occurrence of the intervention condition (mediator) in the population (in the absence of actual intervention).[218–220] In chapter 6, we discuss how natural direct and indirect figures could be interpreted in the context of disparities research.

One important factor worth noting when estimating and interpreting natural effects is that they require rather strict assumptions, which are often impossible to verify in real life. Of particular note in this regard is the cross-world counterfactual assumption underlying the estimation of natural effects. This requires holding the mediator at the level it would be under reference exposure, while changing the exposure from that reference level. In other words, it compares two situations that in practice could not exist simultaneously. It has been argued that this makes the interpretation of natural effects difficult to relate to re-world situations.[214,217,220]

3.2.3.2 The 3-way decomposition

Mediation and interaction effects are known to occur together. A third variable may either be on the pathway of effect from exposure to outcome or may act together with exposure to produce an additively (or multiplicatively) greater (or lesser) effect on the outcome. The traditional approaches to mediation analysis do not easily incorporate the contribution of interaction to the mediated effect. Depending on the approach used, the interaction component may be absorbed

into either the direct or indirect component of effect depending on how these are estimated.[88,221,222]

VanderWeele proposed a 3-way decomposition method, which enables the total effect of the exposure on the outcome to be broken down into three components: one due to mediation alone, one due to mediation and interaction alone, and the last due to neither mediation nor interaction.[215,223] These components have been referred to as the pure direct effect (independent effect of exposure), the pure indirect effect (mediated effect), and the mediated interaction (additional effect from joint action of exposure and third variable acting through the mediated pathway). His approach decomposes the total effect thus:

Equation: 9: $$Y_1 - Y_0 = \left(Y_{1M_0} - Y_{0M_0}\right) + \left(Y_{0M_1} + Y_{0M_0}\right) + (Y_{11} - Y_{10} - Y_{01} + Y_{00})(M_1 - M_0)$$

The first component $\left(Y_{1M_0} - Y_{0M_0}\right)$, represents the pure direct effect, the second $\left(Y_{0M_1} + Y_{0M_0}\right)$, the pure indirect effect, and the third, $(Y_{11} - Y_{10} - Y_{01} + Y_{00})(M_1 - M_0)$ the mediated interaction effect. The components of effect in this case cannot be identified for individuals in data. However, given assumptions 1-4, population-average estimates for these components can be obtained using appropriate regression techniques. The interpretation of these estimates as causal estimates requires further assumptions about confounding. In estimating these components, the same assumptions, which were applied to traditional causal estimation also apply.

A note on notation:

Throughout this study unless otherwise stated, we will present effect measures as a [b, c], where a is our point estimate and b and c are the lower and upper bounds of our 95% confidence

intervals respectively. Summary statistics for categorical variables will be presented as n (%) representing the frequency and percentage of occurrence of each level of the variable

4 ASSESSING THE IMPACT OF NHIS POLICY ON NEONATAL AND INFANT MORTALITY

4.1 Preface

Chapter 4 presents the first of the three manuscripts that make up the contributions to new knowledge in this thesis. I conceived these manuscripts as answering the questions "what", "who" and "how" as they relate the impact of the NHIS on health outcomes. The "what" refers to assessing the effectiveness of the NHIS policy, the "who", which I tackle in the next chapter attempts to answer the question of how the effect of the NHIS has been experienced within strata of the Ghanaian population and finally, the "how", which I address later in chapter 6 adds to our understanding of the mechanisms underlying the effectiveness of the policy.

In this, the first of the manuscripts, I investigated the question of how effective the NHIS has been in improving health outcomes for the population of Ghana as whole. By examining this question, I sought to help close two of the gaps I identified in the literature—the dearth of population-wide evaluations of the policy, and of evaluations using actual health outcome measures. I addressed the former gap by conducting what could be thought of as an intention-to-treat analysis of the effectiveness of the NHIS on early childhood mortality. In this regard, I considered all children born in Ghana after the policy was implemented as affected irrespective of their enrollment status. I based this on the notion that the "intention" of the policy was to reach all Ghanaian residents, and had it been successful, all Ghanaians would have been covered. My contribution to closing the later gap in this manuscript comes from having neonatal and infant mortality as outcomes.

In recent times, approaches to health financing have gained increasing prominence on the global health policy stage—especially as the global community embraces the Sustainable Development Goals (SDGs).[36,224] With more and more countries considering or implementing UHC reforms, lessons learned from established programs such as the NHIS become particularly useful. This is especially important in low- and middle-income contexts such as sub-Saharan Africa, where there haven't been many other examples of successful UHC reform programs to emulate.[75]

The overall health-system-wide effects of major policies such as the NHIS are not easy to anticipate. Although often overseen by inert, monolithic government bureaucracies, health systems are themselves dynamic entities constantly responding to complex needs in ever-changing environments. Major policy changes like the NHIS exert their effects through multiple pathways, both direct and indirect. Such is the case with the NHIS—even though many Ghanaians are not covered under the scheme, its spillover effects indirectly impact their healthcare and health outcomes.[1,44]

The different effect pathways of health policy may drive different outcomes in different directions. For example, by improving utilization of healthcare, the NHIS would be increasing the burden on health facilities and potentially reducing the quality of services. Thus, even policies known to have positive effects on their target population groups may have a neutral or even negative effect overall at the population level.[16,39,129]

Finally, as discussed earlier, health policy evaluations should ideally target actual health outcomes as these more closely reflect the underlying aims which drive such policies. Not many such evaluations have been done, however, perhaps due to a lack of appropriate data. In this study, we leveraged birth history data from multiple Demographic and Health Surveys to be able

to conduct an evaluation of early childhood mortality—an outcome that is both important and a good indicator of health system performance.[225]

The chapter is organized as follows: we first discuss trends in neonatal and infant mortality in Ghana over the study period and introduce the NHIS policy briefly. We then discuss the methods we use for evaluating its impact on neonatal and infant mortality. This section also introduces our data sources and measures. We then present the results of our analyses followed by a discussion of those results. We finally present our conclusions based on our findings.

I conceived this study under the guidance of Drs. Kaufman and Nandi. I conducted the analysis and wrote the manuscript. The manuscript was reviewed by Drs. Kaufman and Nandi and their comments were incorporated into the final version.

4.2 Abstract

Background: Despite making considerable gains in early childhood survival over the past few decades, neonatal and infant mortality in Ghana remain high. The NHIS of Ghana was set up to remove affordability as a barrier to healthcare access. While the literature suggests that the policy has improved access to healthcare for its members, it is unclear that this extends to the population as whole. Also, its impact on distal health outcomes is unclear.
We set out to examine the impact of the NHIS on healthcare utilization (specifically antenatal care usage and skilled attendance at delivery) and early childhood mortality (neonatal and infant mortality), for the entire Ghanaian population, and within socio-economic categories.

Data and methods: We used a difference-in-differences approach with fixed effects using multiple countries as controls and data from the Demographic and Health Survey series.

Results: We found that the NHIS increased antenatal care usage by 10.4 [8.0, 12.3] percentage points with the largest increases seen among the richest wealth quintile and the most educated. Similarly, the policy increased skilled attendance by 6.1 [4.0, 7.8] percentage points with the richest and best educated women seeing an increase in skilled attendance whiles the poorest saw a decrease. The increase in skilled attendance was attenuated when we restricted the data to children born before 2008, thus removing the contribution of the Free Maternal Health program. We found little evidence that the policy had an effect on neonatal or infant mortality.

Conclusion: Our findings suggest that while the NHIS policy may be achieving its goals of improving access to healthcare and healthcare utilization, it may not yet be affecting actual health outcomes such as early childhood mortality.

4.3 Introduction

In this study, we examine the impact of the implementation of the National Health Insurance Scheme policy on healthcare utilization and early childhood mortality in Ghana using data from children born in Ghana from 1993 to 2013. Despite considerable gains made over the previous three decades, levels of neonatal and infant mortality in Ghana at the dawn of the 21st century remained high. According to WHO estimates, 27 of every 1000 children born in Ghana in 2006 did not survive past the first month.[226] For those born in 2008, about 52 of every 1000 are estimated to have died before their first birthday.[227] Reducing the levels of infant and neonatal mortality has been an ongoing priority for the government of Ghana and was given special emphasis under the Millennium Development Goals program. It remains a high priority issue going forward particularly as the country moves to tackle the Sustainable Development Goals.[177,227]

Neonatal and infant mortality are known to be heavily influenced by prenatal and intrapartum events.[228,229] Interventions provided during antenatal healthcare visits, (such as prenatal tetanus vaccinations, antimalarial prophylaxis, preventive HIV screening) and delivery in a well-resourced healthcare setting, attended by skilled personnel have been shown to improve the survival chances for the newborn, especially within the first year after birth.[230–232]

Many women in low- and middle-income countries are however unable to access, and benefit from these interventions. While factors such as socio-cultural barriers to health seeking may be partly responsible, it is often the case that they can't afford these services, or that the services are just not available.[233,234]

This has historically been the situation in Ghana. However, in recent years, Ghana has made important strides in improving the availability of these services through the expansion of health infrastructure and interventions such as the Community-based Health Planning Services (CHPS) program introduced in 1999, which embeds nurses and community health workers within communities to provide preventive care and act as first responders when urgent care is required.[182]

The problem of affordability of care has also been mitigated to some extent since the advent of the National Health Insurance Scheme (NHIS) in 2004. Prior to 2004, Healthcare in Ghana was financed using a fee-for-service model popularly dubbed "cash-and-carry," which required patients to pay (often upfront) out of pocket for services rendered at the point of service. Unsurprisingly, this system prevented many poor people from accessing healthcare services and imposed catastrophic medical costs on those unfortunate enough to suffer medical emergencies, require hospitalization or other major medical interventions such as surgery.[42,235]

The NHIS was implemented in Ghana in 2004 with the stated aim of increasing the affordability and utilization of drugs and other healthcare services, for the population of Ghana in general, and the poorest and most vulnerable in particular. It is mostly financed by a value added tax, with supplementation by social security contributions and premiums. It provides extensive coverage for inpatient, outpatient, emergency and specialist services including pregnancy and delivery care (including caesarian sections), and essential drugs. About 95% of the common health conditions in Ghana are covered under the NHIS.[57] The NHIS requires no copayments, coinsurance or deductibles. In 2008, the government of Ghana added a Free Maternal Healthcare

Program under the NHIS to provide free prenatal and peri-partum healthcare services to all pregnant women, whether previously registered under the NHIS or not.[177]

While the act of Parliament establishing the NHIS mandated it to extend health insurance to all residents of Ghana, the scheme has faced considerable challenges in promoting enrollment. Exact figures on the number of people enrolled in the scheme are not readily available but it has been estimated that only about 45% of the population were active members of the scheme as at 2013.[133,135] Among the factors thought to be responsible for the low coverage levels of the NHIS are the inability of many people to afford premiums. For rural dwellers especially, many of whom are subsistence farmers without reliable sources of income, even the relatively low premium charged represents a considerable drain on household incomes.[77,134]

Previous evaluations of the policy suggest that the NHIS has improved health utilization, among those covered. Brugiavini et al,[63] for example, found that women enrolled under the scheme were more likely to attend antenatal care clinics during pregnancy, deliver at a health facility and be assisted by a trained person at delivery. Members of the NHIS have been shown to use more outpatient visits per-capita, and have lower general household medical expenditure as well as catastrophic health costs.[59,67] The above studies are broadly representative of the general approach used to evaluate the NHIS so far—i.e. comparing outcomes among those insured to outcomes among those uninsured.

This approach leaves several important questions unanswered. Importantly, the impact of the NHIS on the health of the population of Ghana as a whole has not been clearly established—in part because few studies on the matter have adequately handled issues of self-selection into enrollment, and spillover effects.

Self-selection in this case refers to the fact that while supposedly open to all residents of Ghana, enrollment into the scheme is influenced by socio-economic factors and consequently, the membership of the scheme has failed to reflect the makeup of the Ghanaian population. Specifically, it has been found that wealthier and/or formally employed urban dwellers are more likely to enroll in the scheme. Some of the barriers hindering the enrollment of poorer and/or rural-dwelling folk include the registration requirements which often require literacy to navigate, and payment of premiums.[134,236]

By spillover effects we refer to the indirect and unintended effects of policy. For example, while the NHIS has been found to have improved health service utilization, it may have also adversely affected the quality of care received. The increase in demand for services following the removal of financial barriers to accessing healthcare services, has increased the burden on health facilities. While the capacity of the health system has increased both through government and private initiatives, it has not been enough to meet the increased demand for services. There is some evidence that many facilities may have experienced a deterioration in quality as resources and infrastructure are stretched beyond design capacity. This has been supported by reports of long wait times, unfriendly staff and overcrowded facilities.[237,238]

Finally, the ultimate goal of any health system reform is to improve health outcomes for the population in a sustainable manner. Health system reforms such as the NHIS however, target health service utilization. Even if the reforms successfully achieved increased healthcare utilization this would not necessarily translate into improvements in actual health as many determinants of health outcomes exist outside the influence of the health system. For example, environmental exposures are important determinants of actual health outcomes and these are

typically not influenced directly by healthcare policy. Thus, using health service utilization metrics alone to evaluate health system reforms does not give a complete picture of their effectiveness.

In this study, we seek to evaluate the impact of the NHIS on both health utilization (antenatal care usage, skilled attendance at birth) and actual health outcomes (early childhood mortality) from a population-wide perspective. We further explore whether the policy has been equitable in its impact by evaluating its impact within socio-economic categories (household wealth and maternal education).

4.4 Methods

We used a difference-in-differences[189] approach with fixed effects to evaluate the impact of the NHIS policy on antenatal care usage, skilled attendance at delivery, and neonatal and infant mortality. The difference-in-differences approach is typically used to estimate the causal effect of an intervention by comparing outcomes in an intervention group to those in a control group, before and after the intervention. The method assumes that in the absence of time-varying confounding, the effect of confounders is differenced out between the pre- and post-intervention periods, and this approach yields an unbiased estimate of causal effect.[84]

The inclusion of fixed effects for year and country of birth allows us to account for secular trends in the outcome across birth countries, as well as to account for country-specific factors affecting the outcome.[193] In this study, for each outcome, we compared a treated group (children born in Ghana over the study period) to a control group (children born in selected control countries over the same study period).

4.4.1 Data

We used data from the Demographic and Health Surveys (DHS)[116,186] for Ghana and a number of control countries: Egypt, Cameroun, Burkina Faso, Lesotho, Zimbabwe, Malawi, Uganda and Bangladesh. To facilitate comparison across surveys, we used harmonized versions of the DHS data from the International Public Use Microdata Demographic and Health Surveys Series (IPUMS-DHS).[187] The IPUMS-DHS provides variables, which have been made consistent across surveys and between countries. The DHS surveys use a multi-stage sampling approach in which households are randomly selected from within primary sampling units (census enumeration areas in the case of Ghana), which were themselves selected using a probability proportional to size approach from a sampling frame (usually a census list).

We used the DHS birth records data for our analyses of neonatal and infant mortality, and the child records data for our analyses of antenatal care usage and skilled attendance at birth. For the birth records data, all women of child-bearing age in each selected household were interviewed. The birth records data contain information on all the births each woman interviewed has ever had. The data include details such as the date of birth, whether the child was alive, date of death if not alive, and maternal demographic and socio-economic characteristics.[83] The DHS child data are a subset of the births records data, which contain information on births that occurred less than five years before the mother's interview. These data provide additional information on prenatal, intrapartum and postnatal care for each birth.[83]

As with the original DHS surveys, the IPUMS-DHS datasets provide weights to allow the pooling of multiple datasets. We weighted our analyses using the DHS individual sample weights adjusted for the sampling fraction of the female population in each country for each

survey year as per the denormalization procedure recommended for the DHS.[116] We estimated these denormalized weights as

Equation: 10: $$W_{ict} = \frac{n_{ct}}{P_{ct}} * w_i$$

Where

n_{ct} is the number of women aged 15 – 45 years interviewed in country c in survey year *t*

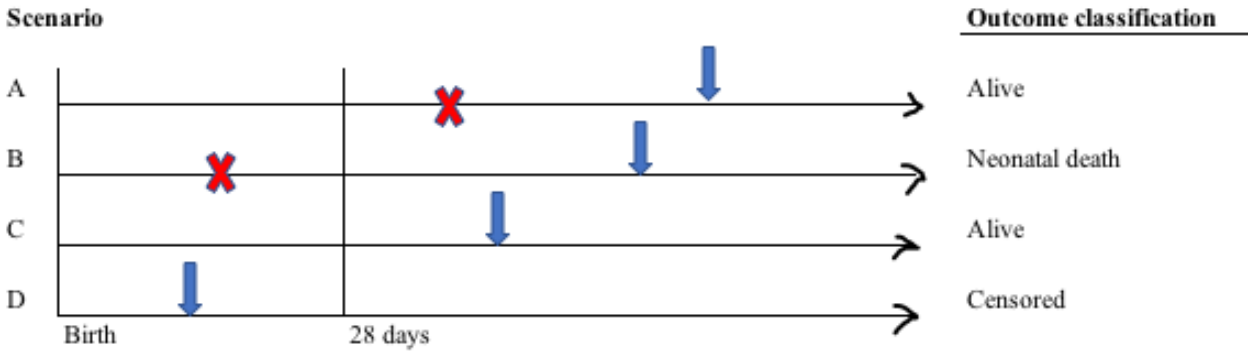
P_{ct} is the population of females aged 15 – 45 years in country c in survey year *t*

w_i is the individual sample weight for each woman *i* interviewed.

4.4.2 Study design

From the data, we extracted four sub-samples of births from 1993 to 2013 based on year of birth (one for each of our outcomes: neonatal mortality, infant mortality, antenatal care usage and skilled attendance at birth). For our infant mortality sample, we excluded all births which occurred less than a year before the mother was interviewed. We similarly excluded all births within 28 days of the mother's interview date for the neonatal mortality sample. We thus excluded children whose outcome (neonatal or infant death) was not yet determined at the time of data collection, and thus avoided having to account for censoring in our analyses. A schematic of our selection procedure for the neonatal mortality sample is given in Figure 4.1 below. A similar process was used for selecting the infant mortality sample, with the threshold of 28 days replaced with 12 months. For our analyses of antenatal care usage and skilled attendance at birth, we assembled two samples of births from the DHS child dataset from which we excluded observations missing on the respective outcomes.

Figure 4-1: Procedure for assembling samples for neonatal and infant mortality analyses



Notes:
Time flows from left to right
X indicates date of death of child
Date of birth of child indicates time 0
Downward pointing arrows indicate date at which mother was interviewed

4.4.3 Measures

Our treatment group consisted of children born in Ghana over the study period. We examined four outcomes in this study: neonatal mortality defined as death within the first 28 days post-partum; infant mortality defined as death within the first 12 months of birth; antenatal care usage defined as having had at least four antenatal care visits during the corresponding pregnancy (based on the WHO recommended guidelines for ANC[239,240]); and skilled attendance at birth defined as delivery in an appropriate health facility attended by a qualified medical professional. Appropriate facilities included health clinics, district and regional hospitals and registered private maternity homes. A skilled attendant in this case refers to a qualified nurse, midwife or doctor. Traditional birth attendants, trained or not, were not counted as skilled attendants (based on the fact that they often lack adequate training and resources).[241,242]

We examined the heterogeneity of the impact of the NHIS by maternal educational level and household wealth. Maternal education was assessed as a 3-category variable (none, primary, secondary or higher) representing the highest level of education completed by the child's mother. Household wealth was assessed as quintiles of an asset score derived from a principal-components analysis of household assets.[243] This score was calculated separately for each country and survey year.

4.4.4 Control country selection

The validity of any causal inference made from a difference-in-differences analysis depends on the use of a control group whose average outcome is a reasonable approximation of the average of the counterfactual outcomes for the treated group in the post-intervention period. In this study, we used multiple control countries to account for country-specific factors which would drive trends in the outcome.[193] We selected the control countries based on a mix of empirical and substantive criteria. Eligible control countries:

1. Should not have implemented a national health insurance program or similar major national health financing mechanism over the study period
2. Should be low- or middle-income countries (by GDP, World Bank classification[244])
3. Should not show empirical evidence of a violation of the parallel trends assumption of the difference-in-differences analytic approach in the pre-intervention period. (We discuss our approach to assessing the last criteria below)

Based on these criteria, we chose Lesotho, Egypt and Cameroun as control countries for our neonatal mortality analysis, Cameroon, Burkina Faso and Zimbabwe as controls for our infant mortality analysis. For usage of antenatal care, we used Malawi and Bangladesh as controls, while for skilled attendance at birth, we used Bangladesh and Uganda.

4.4.5 Identification of effect

The identification of the causal effect in a difference-in-difference analysis is dependent on the validity of the assumption of parallel trends[190] viz. that the time trends in the outcome are such that, there would be a constant difference in the outcome between treated and control groups over time, in the absence of the intervention. The parallel trends assumption cannot be objectively verified as it represents a counterfactual which is not observed, however, a comparison of trends in the outcome in the pre-intervention period can help identify violations of this assumption.

Our confidence in the validity of the assumption and consequently the identifiability of the causal effect depends on having an appropriate control group. In choosing our control groups, we evaluated the parallel trends assumption in two ways: statistically and graphically. Statistically, we estimated linear regression models of the outcomes using data from the pre-intervention period with fixed effects terms for country and year of birth, as well as interaction terms between the country and birth year indicators. We then conducted F-tests for the joint significance of the coefficients of the interaction terms. Graphically, we plotted the trends in each outcome by treatment assignment and visually compared the trends.

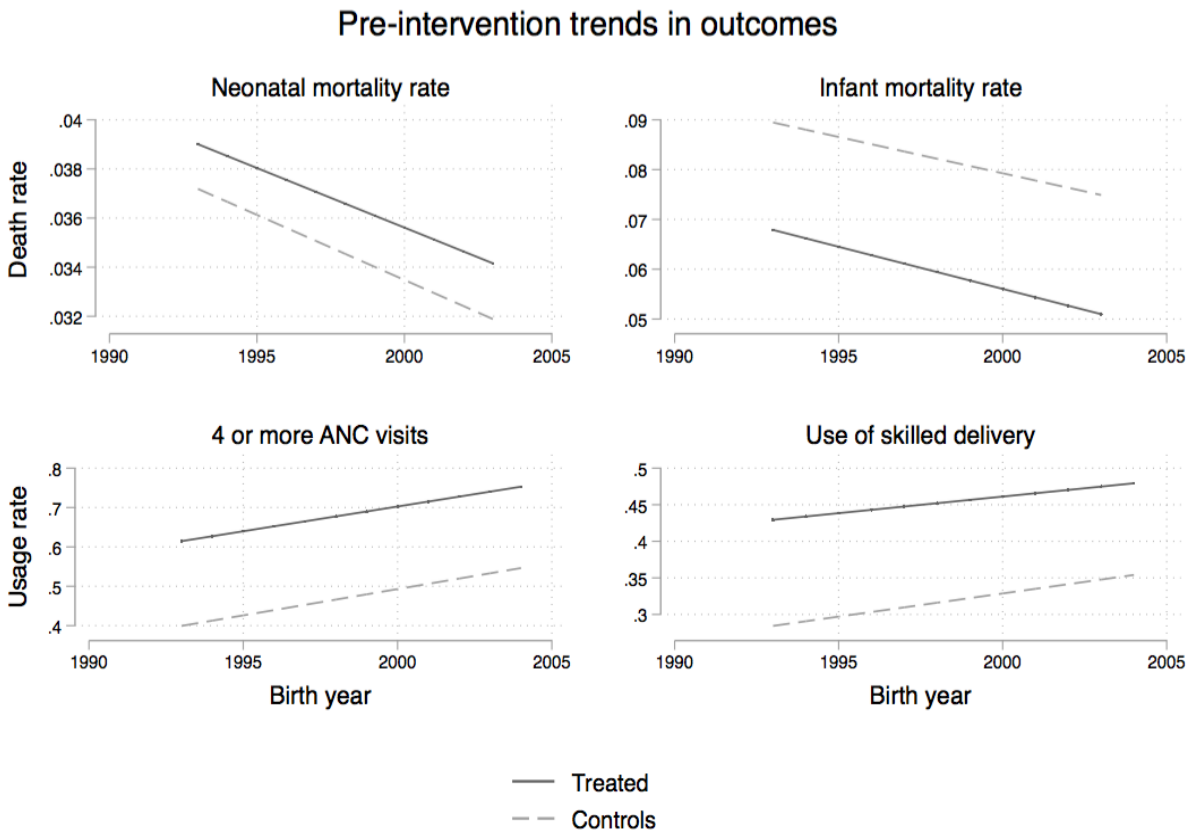


Figure 4-2 Pre-intervention trends in neonatal mortality, infant mortality, antenatal care usage and skilled attendance comparing treated and control samples (1993 to 2003)

Note:
Graphs were obtained by plotting fitted predictions from weighted linear models of outcomes with quarter of birth (as continuous), treatment and interaction between treatment and quarter of birth as predictors. Weights obtained as in equation 10

4.4.6 Estimation of effect

Under the assumption of parallel trends, the effect of a binary intervention (X) on an outcome (Y) is given by:

Equation: 11: $E(Y \mid X = 1) - E(Y \mid X = 0) = [E(Y \mid X = 1, T = 1) - E(Y \mid X = 1, T = 0)] - [E(Y \mid X = 0, T = 1) - E(Y|X = 0, T = 0)]$

Where:

T = time period (0 = pre-intervention, 1 = post-intervention)

$E(Y|X = x, T = t)$ = mean outcome for group *x*, in time period *t*

We estimated our effect measure from a linear probability model of the form

Equation: 12: $$Y_{ict} = \beta_0 + \beta_1 X_{ic} + \beta_2 T_{it} + \beta_3 X_{ic} * T_{it} + \boldsymbol{\delta'} \boldsymbol{C_{ic}} + \boldsymbol{\phi'} \boldsymbol{P_{it}} + \epsilon_{ict}$$

Y_{ict} is the probability of the outcome for individual *i* born in country *c* at time *t*

X_{ic} is an indicator of being born in Ghana (vs. control country) for individual *i*

T_{it} is an indicator that individual *i* was born in the post (vs. pre) intervention period

$\boldsymbol{C_{ic}}$ is vector of country-dummy variables with $\boldsymbol{\delta'}$ being the vector of their corresponding coefficients

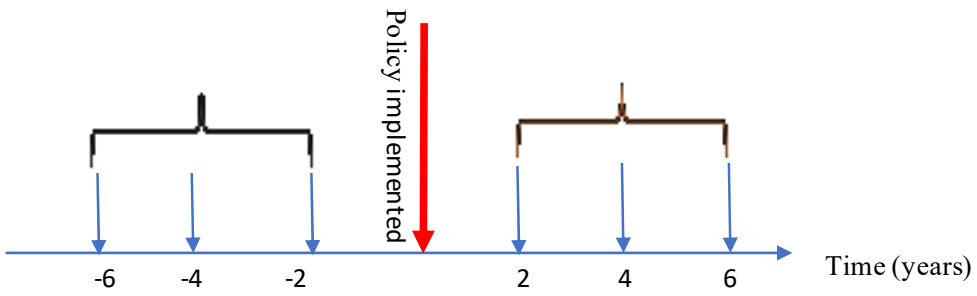
$\boldsymbol{P_{it}}$ is a vector of year fixed-effects terms with $\boldsymbol{\phi'}$ being the vector of their corresponding coefficients

We fit a linear probability model so we could assess the assumption of parallel linear trends and to allow for the interpretation of the coefficients from our model as risk differences. We checked the suitability of the linear model by comparing the estimates of prevalence of our outcomes from the linear probability model with those predicted from a logistic model, and also with published estimates of the prevalence of our outcomes over the study period[226]—we found these values to be similar.

From the above model, β_3, the coefficient of our interaction term represents our difference-in-differences estimate of effect. It captures the change in the expected value of the outcome comparing intervention and control groups, between the pre- and post-intervention period.

We included fixed effects terms for country to account for time-fixed country-level differences and fixed effects terms for year of birth to account for secular trends in the outcome differing between countries. We also estimated effects adjusted for maternal education and household wealth quintile by adding these terms to the model above.

Figure 4-3: Illustration of temporal relationship between time-varying effects (leads and lags)



Note: lead and lag effects were assessed in relation to being born point in time indicated by corresponding arrow

Note: lead and lag effects were assessed as the effect of being born at a point in time in relation to the time indicated by corresponding arrow

We explored heterogeneity of the policy effect by socio-economic status by adding indicators of maternal education level and household asset wealth category and including interactions between these variables and our treatment, time, and fixed-effects variables. We then estimated the effects of the policy within each strata of our socio-economic stratum variables. We tested for heterogeneity globally for each variable by conducting an F-test.

We estimated our standard errors using a non-parametric bootstrap procedure.[196,245,246]

4.4.7 Sensitivity analyses

We conducted two checks on the robustness of our findings. Firstly, we explored the occurrence of time-varying effects by fitting a model including interactions between indicators of being born at various time points over the study period and being in the treated or control group. These models were of the form

Equation: 13: $Y_{ict} = \beta_0 + \beta_1 X_i + \beta_2 T_{it} + \beta_3 X_i * T_{it} + \sum_m \gamma X_i (T_{it} + m)_i + \boldsymbol{\delta' C_{ic}} + \boldsymbol{\phi' P_i} + \epsilon_{ict}$

Where $m \in \{-6, -4, -2, 2, 4, 6\}$ and $X_i(T + m)_i$ represents an interaction between indicators of being born at time $T + m$ and treatment status X.

A visual representation of the time varying effects is given in Figure 4-3. We refer to the indicators of being born after time points which precede the actual implementation date as lead effects and these, if non-zero, would indicate that the effect of the policy was anticipated before it came into force. This would suggest a violation of the parallel trends assumption. The indicators of being born after time points in the post-intervention period (referred to here as lag effects), if non-zero, indicate that the effect of the policy either increased or decreased (as the case may be) over the post-intervention period.

We also explore the impact of the Free Maternal Healthcare program which was started in 2008[177] on our outcomes. This program made antenatal and delivery services free for pregnant women in Ghana irrespective of NHIS registration status. This in effect removed any cost-barriers to NHIS coverage, and consequently, to utilization of healthcare services. To get a sense for the contribution of the effects of this program to our findings, we conducted additional analyses using only data from children born before 2008—thus excluding the effects of this program.

All analyses were done in STATA 13.[247]

4.5 Results

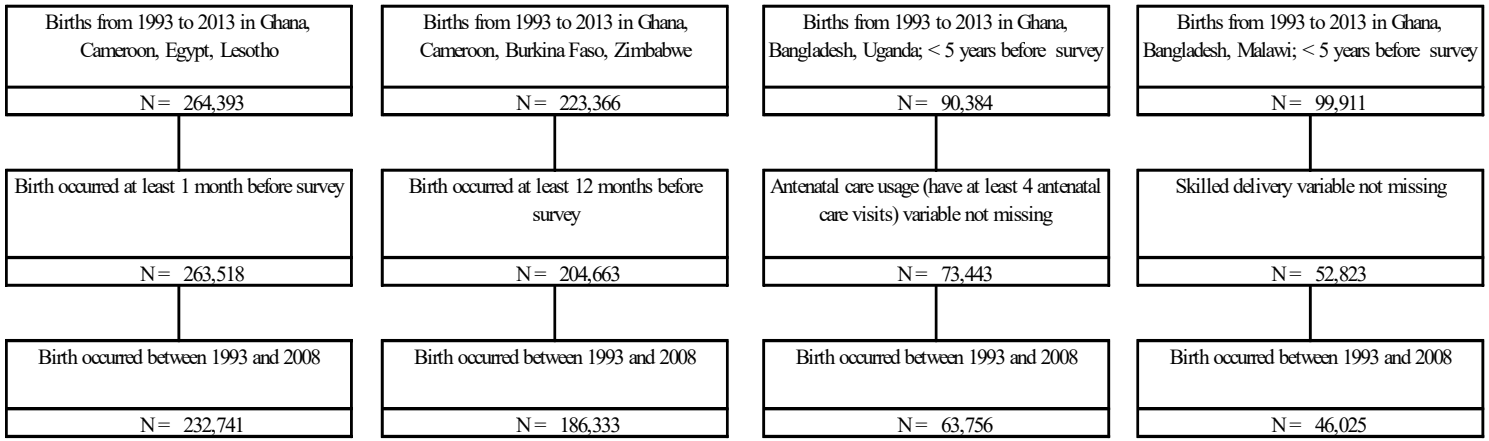
A flowchart showing how the various samples were derived is presented in Figure 4.4. Tables 4.1, 4.2 and 4.3 present the characteristics of our samples and distribution of outcomes within our sample. Tables 4.4, 4.5 and 4.6 present the results from our main and sensitivity analyses.

There were 263,518 births in our neonatal mortality sample (875 births were excluded because they occurred less than a month to the mother's interview), 204,663 births in our infant mortality sample (18,703 births were excluded as they occurred less than 12 months before the mother was interviewed), 73,443 births in our antenatal care sample and 52,823 births in our skilled attendance sample.

The socio-economic characteristics of the mothers in each study sample are presented in in Table 4.1. Across all samples, the mothers were predominantly rural-dwellers (almost two-thirds of all respondents). Respondents in the treated group were more likely to have no education and less likely to have secondary or higher education compared to those in the control samples. Household wealth was distributed in a similar manner for both treated and control groups across all samples.

We observed a generally decreasing trend in neonatal and infant mortality for both treated and control groups over the study period. The neonatal mortality rate decreased from 34.4 [32.6, 36.2] to 33.0 [30.5, 35.6] per 1000 LB for the treated group, and from 36.6 [34.0, 39.3] to 31.1 [27.5, 34.7] per 1000 LB for the control group, going from the pre-intervention to post intervention periods respectively. The equivalent changes in infant mortality over the same period were from 82.1 [80.2, 84.0] to 67.6 [65.0, 70.3] per 1000 LB for the control group, and from 59.7 [56.2, 63.2] to 48.6 [44.2, 53.1] per 1000 LB for the treated group.

Figure 4-4 Sample dispositions



Notes:
No exclusions on missingness on child death outcomes as this information was complete in the raw data. Countries listed in initial sampling stage apart from Ghana served as control countries for that outcome. Children born in Ghana were considered treated

Table 4-1: Distribution of socio-economic characteristics of respondents

	Neonatal mortality sample			Infant mortality cohort			ANC cohort			Skilled delivery cohort		
	Control N=222,957	Treated N=40,561	Total N=263,518	Control N=167,040	Treated N=37,623	Total N=204,663	Control N=61,262	Treated N=12,181	Total N=73,443	Control N=37,247	Treated N=15,576	Total N=52,823
Maternal education level												
None	65,402 (29.3)	17,902 (44.1)	83,304 (31.6)	78,162 (46.8)	16,632 (44.2)	94,794 (46.3)	34,885 (56.9)	4,940 (40.6)	39,825 (54.2)	12,285 (33.0)	6,422 (41.2)	18,707 (35.4)
Primary	60,109 (27.0)	8,562 (21.1)	68,671 (26.1)	45,650 (27.3)	7,708 (20.5)	53,358 (26.1)	12,378 (20.2)	2,729 (22.4)	15,107 (20.6)	11,125 (29.9)	3,508 (22.5)	14,633 (27.7)
Secondary or higher	97,446 (43.7)	14,097 (34.8)	111,543 (42.3)	43,217 (25.9)	13,283 (35.3)	56,500 (27.6)	13,996 (22.8)	4,512 (37.0)	18,508 (25.2)	13,834 (37.1)	5,646 (36.2)	19,480 (36.9)
Household wealth												
Poorest	53,821 (24.1)	13,213 (32.6)	67,034 (25.4)	37,079 (22.2)	12,315 (32.7)	49,394 (24.1)	12,415 (20.3)	3,739 (30.7)	16,154 (22.0)	8,258 (22.2)	5,007 (32.1)	13,265 (25.1)
Poor	46,892 (21.0)	9,194 (22.7)	56,086 (21.3)	35,349 (21.2)	8,505 (22.6)	43,854 (21.4)	12,342 (20.1)	2,658 (21.8)	15,000 (20.4)	7,573 (20.3)	3,467 (22.3)	11,040 (20.9)
Middle	43,391 (19.5)	7,509 (18.5)	50,900 (19.3)	34,820 (20.8)	6,976 (18.5)	41,796 (20.4)	12,310 (20.1)	2,224 (18.3)	14,534 (19.8)	7,111 (19.1)	2,780 (17.8)	9,891 (18.7)
Rich	40,624 (18.2)	5,946 (14.7)	46,570 (17.7)	33,065 (19.8)	5,480 (14.6)	38,545 (18.8)	12,167 (19.9)	1,978 (16.2)	14,145 (19.3)	6,951 (18.7)	2,392 (15.4)	9,343 (17.7)
Richest	38,229 (17.1)	4,699 (11.6)	42,928 (16.3)	26,727 (16.0)	4,347 (11.6)	31,074 (15.2)	12,028 (19.6)	1,582 (13.0)	13,610 (18.5)	7,354 (19.7)	1,930 (12.4)	9,284 (17.6)
Residence												
Urban**	81,768 (36.7)	13,587 (33.5)	95,355 (36.2)	47,001 (28.1)	12,799 (34.0)	59,800 (29.2)	17,078 (27.9)	3,837 (31.5)	20,915 (28.5)	10,368 (27.8)	4,829 (31.0)	15,197 (28.8)
Rural	141,189 (63.3)	26,974 (66.5)	168,163 (63.8)	120,039 (71.9)	24,824 (66.0)	144,863 (70.8)	44,184 (72.1)	8,344 (68.5)	52,528 (71.5)	26,879 (72.2)	10,747 (69.0)	37,626 (71.2)

Note:
Unweighted frequencies and proportions.
Treated country is Ghana
Control countries for neonatal mortality were Cameroon, Egypt and Lesotho; control
Control countries for infant mortality were Cameroon, Burkina Faso and Zimbabwe
Control countries for antenatal care usage were Bangladesh and Uganda
Control countries for skilled attendance ware Bangladesh and Malawi

Table 4-2: Neonatal and infant mortality rates by rural/urban residence comparing pre- and post-Intervention

	Neonatal mortality (deaths per 1000 live births)				Infant mortality (deaths per 1000 live births)			
	Controls		Treated		Controls		Treated	
	pre	post	pre	post	pre	post	pre	post
Maternal education level								
None	37.5 [34.7, 40.4]	28.6 [24.8, 32.5]	36.7 [32.9, 40.6]	30.8 [25.2, 36.4]	95.3 [92.6, 98.0]	77.7 [73.4, 81.9]	65.9 [60.4, 71.3]	54.5 [47.1, 61.9]
Primary	38.9 [35.9, 41.9]	41.0 [36.3, 45.8]	37.6 [32.0, 43.2]	32.8 [25.1, 40.5]	70.0 [66.7, 73.3]	63.5 [58.8, 68.1]	59.1 [51.9, 66.4]	49.8 [40.1, 59.5]
Secondary +	26.7 [23.8, 29.6]	26.7 [23.4, 30.0]	35.9 [31.2, 40.5]	30.5 [24.8, 36.1]	47.2 [44.1, 50.3]	50.7 [46.9, 54.5]	53.8 [48.1, 59.6]	44.2 [37.5, 50.9]
Household wealth								
Poorest	43.6 [39.8, 47.5]	36.1 [31.0, 41.3]	32.2 [28.0, 36.4]	30.7 [24.7, 36.7]	95.0 [90.8, 99.2]	77.7 [71.8, 83.6]	57.2 [51.7, 62.7]	54.1 [46.1, 62.1]
Poor	34.8 [31.0, 38.6]	34.7 [29.4, 40.0]	40.2 [34.2, 46.2]	25.5 [19.4, 31.5]	95.8 [91.4, 100.2]	75.8 [69.8, 81.8]	68.8 [60.5, 77.0]	43.4 [35.0, 51.8]
Middle	35.1 [30.9, 39.3]	28.2 [23.5, 32.9]	43.0 [36.7, 49.3]	28.1 [20.2, 35.9]	77.9 [73.9, 81.8]	70.8 [65.0, 76.6]	68.1 [59.9, 76.2]	42.8 [33.4, 52.3]
Rich	32.4 [28.1, 36.7]	40.5 [33.0, 48.1]	32.6 [26.0, 39.1]	31.1 [21.4, 40.8]	75.1 [70.9, 79.3]	57.5 [52.1, 62.8]	52.1 [43.4, 60.8]	48.8 [36.8, 60.8]
Richest	24.7 [20.7, 28.6]	23.9 [18.6, 29.3]	33.9 [26.7, 41.0]	42.4 [31.0, 53.8]	58.0 [53.5, 62.4]	50.5 [44.6, 56.3]	46.6 [38.1, 55.2]	54.5 [41.7, 67.3]
Urban/rural residence								
Urban	26.4 [23.7, 29.1]	26.5 [22.4, 30.5]	34.9 [30.2, 39.5]	34.3 [28.4, 40.3]	61.4 [58.1, 64.7]	55.2 [50.8, 59.6]	51.3 [45.6, 57.0]	51.0 [43.9, 58.2]
Rural	38.0 [35.7, 40.3]	36.0 [32.8, 39.2]	37.6 [34.4, 40.8]	28.6 [24.1, 33.1]	88.4 [86.1, 90.6]	72.0 [68.8, 75.2]	64.7 [60.3, 69.1]	46.7 [41.1, 52.4]
Total	34.4 [32.6, 36.2]	33.0 [30.5, 35.6]	36.6 [34.0, 39.3]	31.1 [27.5, 34.7]	82.1 [80.2, 84.0]	67.6 [65.0, 70.3]	59.7 [56.2, 63.2]	48.6 [44.2, 53.1]

Note: Overall estimates are mean predicted probabilities from weighted logistic regression models with rural/urban residence, an indicator of being in the post-intervention period and an interaction between rural/urban residence and the indicator of being in the post-intervention period. For estimates within strata of covariates, each covariate was added to the model together with interactions between the covariates and the other model terms

Table 4-3: Antenatal Care Usage and Skilled attendance Rates by Rural/Urban Residence comparing Pre- and Post-Intervention

	ANC usage (% used ANC)				Skilled delivery (% had skilled delivery)			
	Controls		Treated		Controls		Treated	
	pre	post	pre	post	pre	post	pre	post
Maternal education level								
None	28.5 [27.6, 29.4]	34.2 [33.0, 35.4]	55.6 [53.7, 57.5]	78.9 [76.7, 81.1]	2.3 [2.0, 2.7]	8.6 [7.5, 9.7]	26.6 [25.1, 28.0]	47.8 [45.5, 50.0]
Primary	47.4 [45.2, 49.5]	47.6 [44.9, 50.3]	66.4 [63.9, 68.8]	80.6 [78.0, 83.2]	5.6 [5.0, 6.1]	16.1 [14.7, 17.4]	43.0 [40.8, 45.2]	64.4 [61.8, 66.9]
Secondary +	71.5 [69.3, 73.7]	58.1 [56.0, 60.3]	81.5 [79.9, 83.1]	92.2 [91.0, 93.5]	21.4 [20.4, 22.5]	39.5 [38.3, 40.7]	66.8 [65.2, 68.5]	84.9 [83.5, 86.2]
Household wealth								
Poorest	16.5 [15.0, 18.0]	23.9 [22.0, 25.9]	50.5 [48.1, 52.8]	74.8 [72.3, 77.2]	2.0 [1.5, 2.4]	9.3 [8.1, 10.5]	20.5 [18.8, 22.2]	39.9 [37.4, 42.3]
Poor	21.5 [19.9, 23.1]	27.8 [25.8, 29.8]	61.8 [59.2, 64.4]	80.5 [78.0, 83.0]	2.7 [2.2, 3.2]	14.3 [12.8, 15.9]	29.4 [27.2, 31.6]	58.1 [55.3, 60.8]
Middle	25.7 [24.0, 27.3]	31.7 [29.5, 33.9]	66.1 [63.5, 68.8]	86.0 [83.2, 88.7]	4.4 [3.7, 5.0]	21.4 [19.7, 23.1]	44.2 [41.7, 46.8]	74.6 [71.7, 77.4]
Rich	37.8 [35.7, 39.9]	43.0 [40.4, 45.5]	82.4 [80.1, 84.7]	93.5 [91.4, 95.5]	9.0 [8.0, 9.9]	34.3 [32.4, 36.3]	69.5 [66.9, 72.1]	90.1 [88.2, 92.0]
Richest	67.9 [65.8, 70.0]	68.8 [66.2, 71.3]	92.9 [91.1, 94.6]	97.9 [96.6, 99.2]	29.9 [28.5, 31.3]	59.1 [57.1, 61.1]	88.8 [86.8, 90.7]	96.2 [94.7, 97.7]
Urban/rural residence								
Urban	60.7 [58.8, 62.6]	59.9 [57.5, 62.4]	86.5 [84.9, 88.1]	92.1 [90.8, 93.5]	24.7 [23.6, 25.8]	46.3 [44.6, 47.9]	78.7 [76.9, 80.4]	89.1 [87.9, 90.3]
Rural	23.7 [22.8, 24.5]	31.3 [30.3, 32.4]	60.4 [59.0, 61.8]	81.3 [79.8, 82.8]	5.0 [4.7, 5.4]	20.6 [19.8, 21.4]	31.9 [30.7, 33.1]	55.1 [53.4, 56.7]
Total	33.3 [32.5, 34.1]	38.1 [37.1, 39.1]	68.1 [67.0, 69.2]	86.1 [85.1, 87.2]	8.2 [7.9, 8.6]	26.4 [25.7, 27.2]	45.5 [44.5, 46.5]	69.9 [68.8, 71.0]

Note: Overall estimates are mean predicted probabilities from weighted logistic regression models with rural/urban residence, an indicator of being in the post-intervention period and an interaction between rural/urban residence and the indicator of being in the post-intervention period. For estimates within strata of covariates, each covariate was added to the model together with interactions between the covariates and the other model terms

Table 4-4: Impact of NHIS on neonatal and infant mortality, antenatal care usage and skilled attendance in Ghana (1993 to 2013)

	Neonatal mortality (additional deaths per 1000 live births)	Infant mortality (additional deaths per 1000 live births)	>= 4 ANC visits (percentage-point increase)	Use of skilled delivery (percentage-point increase)
Main Effects estimates				
Unadjusted	-2.5 [-7.8 , 2.3]	1.2 [-5.2 , 7.8]	10.4 [8.0 , 12.3]	3.9 [1.9 , 5.6]
Adjusted	-2.7 [-8.3 , 2.2]	0.2 [-6.4 , 6.8]	10.5 [8.2 , 12.5]	6.1 [4.0 , 7.8]
Effects within categories of HH wealth				
Poorest	11.9 [-1.2 , 28.5]	14.3 [-4.1 , 33.5]	4.6 [0.2 , 8.1]	-5.3 [-8.1 , -2.2]
Poor	-7.7 [-21.5 , 4.9]	11.5 [-3.2 , 27.9]	2.1 [-2.3 , 6.1]	-6.1 [-11.0 , -1.8]
Middle	-8.4 [-19.0 , 2.4]	-22.4 [-37.5 , -5.9]	12.9 [6.3 , 17.8]	8.6 [4.0 , 13.2]
Rich	-13.5 [-23.9 , -1.9]	-7.9 [-24.2 , 7.6]	11.2 [6.4 , 16.0]	11.2 [7.2 , 14.9]
Richest	8.6 [-2.1 , 18.0]	10.9 [-0.9 , 22.4]	15.0 [10.0 , 20.1]	7.4 [3.4 , 11.4]
p-value for test of heterogeneity	0.015	0.002	< 0.0001	< 0.0001
Effects within categories of maternal education				
None	-4.4 [-14.6 , 4.6]	-12.0 [-22.3 , -1.9]	10.6 [7.2 , 13.8]	3.7 [0.5 , 6.8]
Primary	-4.1 [-14.8 , 8.1]	-4.2 [-17.3 , 11.2]	8.9 [4.8 , 13.3]	9.1 [5.1 , 13.6]
Secondary +	5.8 [-2.7 , 13.6]	7.4 [-4.1 , 18.7]	16.2 [12.2 , 20.1]	5.8 [2.0 , 8.9]
p-value for test of heterogeneity	0.170	0.047	0.028	0.129

HH = household; ANC = Antenatal care
Note:
Effects are risk differences
Adjusted estimates are adjusted for maternal education and household wealth
Treated country is Ghana
Control countries for neonatal mortality were Cameroon, Egypt and Lesotho; control
Control countries for infant mortality were Cameroon, Burkina Faso and Zimbabwe
Control countries for antenatal care usage were Bangladesh and Uganda
Control countries for skilled attendance ware Bangladesh and Malawi

Table 4-5: Impact of NHIS on neonatal and infant mortality, antenatal care usage and skilled attendance in Ghana (1993 to 2008)

	Neonatal mortality (additional deaths per 1000 live births)	Infant mortality (additional deaths per 1000 live births)	>= 4 ANC visits (percentage-point increase)	Use of skilled delivery (percentage-point increase)
Main Effects estimates				
Unadjusted	-4.2 [-10.1 , 2.7]	5.7 [-1.8 , 13.6]	10.5 [8.1 , 13.2]	1.6 [-0.8 , 3.9]
Adjusted	-4.3 [-10.3 , 2.6]	5.1 [-2.6 , 12.7]	10.1 [7.3 , 12.9]	1.8 [-1.0 , 4.7]
Effects within categories of HH wealth				
Poorest	15.5 [-9.0 , 34.2]	28.2 [9.2 , 49.8]	4.6 [0.3 , 8.8]	-3.1 [-8.2 , 2.0]
Poor	-14.2 [-29.7 , 2.1]	10.1 [-9.3 , 29.6]	9.6 [5.2 , 14.3]	-2.8 [-8.3 , 3.2]
Middle	-9.4 [-21.3 , 2.7]	-16.1 [-31.7 , 1.0]	11.1 [4.4 , 18.7]	7.0 [0.5 , 14.3]
Rich	-14.3 [-26.8 , -0.1]	-6.3 [-22.5 , 9.6]	9.0 [2.5 , 14.5]	9.7 [4.6 , 15.8]
Richest	7.6 [-2.6 , 16.4]	17.0 [3.3 , 34.2]	12.2 [6.5 , 17.3]	-5.0 [-8.6 , -0.9]
p-value for test of heterogeneity	0.015	0.002	< 0.0001	< 0.0001
Effects within categories of maternal education				
None	-5.9 [-15.5 , 3.6]	-10.5 [-21.8 , 1.8]	10.9 [6.2 , 14.6]	1.4 [-1.9 , 5.1]
Primary	-6.2 [-18.4 , 8.3]	5.6 [-10.2 , 20.4]	6.7 [1.0 , 12.1]	3.5 [-2.0 , 8.9]
Secondary +	5.9 [-5.0 , 16.7]	8.5 [-2.7 , 20.7]	16.2 [11.2 , 20.6]	0.4 [-3.6 , 3.8]
p-value for test of heterogeneity	0.170	0.047	0.028	0.129

HH = household; ANC = Antenatal care
Note:
Effects are risk differences
Adjusted estimates are adjusted for maternal education and household wealth
Treated country is Ghana
Control countries for neonatal mortality were Cameroon, Egypt and Lesotho; control
Control countries for infant mortality were Cameroon, Burkina Faso and Zimbabwe
Control countries for antenatal care usage were Bangladesh and Uganda
Control countries for skilled attendance ware Bangladesh and Malawi

Antenatal care usage and skilled attendance at birth on the other hand, increased over the study period on average for both treated and control groups. The proportion of pregnant women receiving the recommended minimum of four antenatal care visits increased from 33.3 [32.5, 34.1] percent to 38.1 [37.1, 39.1] percent in the control group and from 68.1 [67.0, 69.2] percent to 86.1 [85.1, 87.2] percent for women in the intervention group. 8.2 [7.9, 8.6] percent of women in the control group received skilled attendance in the pre-intervention period compared to 26.4 [25.7, 27.2] percent in the post-intervention period. The equivalent change for women in the treated group was from 45.5 [44.5, 46.5] percent receiving skilled attendance before the intervention to 69.9 [68.8, 71.0] percent doing so after the intervention.

There was a discernible gradient in neonatal and infant mortality across SES categories. With a few exceptions, infant and neonatal mortality generally decreased with increasing wealth and maternal education. Skilled attendance and antenatal care usage rates, on the other hand, increased with increasing maternal education and household wealth.

The advent of the NHIS was associated with an increase in ANC usage of 10.5 [8.2, 12.5] percentage-points. Within categories of household wealth, the largest effects were seen among the richest quintile (15.0 [10.0, 20.1] percentage-point increase) and mothers with at least a secondary school education (8.9 [4.8, 13.3] percentage-point increase). When the data were restricted to the period before the introduction of the Free Maternal Care program, essentially the same pattern of effect was seen. The overall effect of the policy was an increase of 10.1 [7.3, 12.9] percentage points in ANC usage. The effect seen among the richest quintile was now 12.2 [6.5, 17.3] percentage-points with an increase of 6.7 [1.0, 12.1] percentage-points.

The advent of the NHIS was associated with an increase of 6.1 [4.0, 7.8] percentage points in skilled attendance at birth overall. This gain was not evenly distributed across socio-economic classes with a change of -5.3 [-8.1, -2.2] percentage-points seen among the poorest women compared to 7.4 [3.4, 11.4] percentage points among the richest women. Similarly, women with no education saw a gain of percentage points compared to 3.7 [0.5, 6.8] percentage-points among those with at least a primary school education. The impact of the policy on skilled attendance was essentially eliminated when the contribution of the Free Maternal Health Policy was taken out. The overall effect decreased to a 1.8 [-1.0, 4.7] percentage-points.

Using data for the full study sample, we found no evidence of an overall effect of the policy on neonatal mortality (adjusted DD estimate = -2.7 [-8.3, 2.2] additional deaths per 1000 LB) or on infant mortality (adjusted DD estimate = 0.2 [-6.4, 6.8] additional deaths per 1000 LB). We likewise found no evidence of an effect within strata of SES. The story was the same when we restricted our data to children born before 2008—there was no evidence for an effect of the NHIS on neonatal mortality (adjusted DD estimate = -4.3 [-10.3, 2.6]) or infant mortality (adjusted DD estimate = 5.1 [-2.6, 12.7]).

Table 4-6: Time-varying effects of the policy intervention on outcomes

	Neonatal mortality (additional deaths per 1000 live births)	Infant mortality (additional deaths per 1000 live births)	>= 4 ANC visits (percentage-point increase)	Use of skilled delivery (percentage-point increase)
Lead terms				
- 2 years	0.7 [-8.5 , 9.2]	-10.6 [-20.9 , 2.1]	2.2 [-5.5 , 10.0]	4.4 [2.3 , 6.5]
- 4 years	-1.3 [-8.3 , 6.8]	-0.6 [-9.0 , 8.0]	1.7 [-5.5 , 9.8]	4.1 [1.6 , 6.1]
- 6 years	-2.8 [-8.4 , 3.1]	2.8 [-3.7 , 10.5]	0.2 [-6.6 , 11.1]	4.1 [1.8 , 6.1]
Lag terms				
+ 2 years	-2.1 [-8.0 , 3.6]	-0.9 [-8.2 , 5.9]	10.5 [8.0 , 13.1]	1.1 [-0.8 , 3.2]
+ 4 years	-1.6 [-7.3 , 3.5]	1.7 [-4.3 , 7.6]	10.0 [7.7 , 12.0]	1.7 [-0.2 , 3.3]
+ 6 years	0.3 [-4.3 , 5.9]	1.3 [-4.9 , 7.8]	7.4 [5.1 , 9.4]	1.2 [-0.5 , 3.0]

Note: lead terms replace treatment year with alternative years preceding the year of intervention; lag terms replace year of intervention with years after the year of intervention

The results from the models with lead terms suggest that effects of the policy on ANC and skilled attendance at delivery from the full samples, were not anticipated (Table 4-6). This adds further support to the observed effects being attributable to the implementation of the NHIS. We found little evidence suggesting that the effect of the policy on these outcomes was sustained over time except for the increase in antenatal care usage which seems to have persisted for at least four years post-implementation.

4.6 Discussion

We set out to explore the impact of the NHIS on healthcare utilization and early childhood mortality and found that the policy had a positive effect on antenatal care usage and to a more limited extent on skilled attendance at birth. Women from the wealthiest households appear to have benefited the most in terms of improved antenatal care usage and the poorest women may have actually been made worse off in terms of skilled attendance at birth. We found little evidence the advent of the NHIS had any effect on neonatal or infant mortality, either overall or within SES categories.

These findings agree with those of previous studies, which found the NHIS policy has enabled more women to use antenatal care services since its inception.[150,248,249] The overall increases in ANC usage and skilled attendance after implementation of the policy support the notion that cost barriers were indeed a major obstacle to the utilization of healthcare services. However, the poorest women who should have benefited most from the NHIS in this regard appear to have benefited the least. Indeed, for skilled attendance at birth, some of the poorer women may have actually been made worse off since the policy came into effect.

These differences in the impact of the policy could be due in part to the fact that, that while affordability of care at the point of care may have been improved, other cost elements involved in seeking care may not have been ameliorated and may still be hindering access and utilization of healthcare services. For example, seeking care requires that the woman pay for transportation, possible overnight stays and feeding, in addition to losing potential income from missing work. These costs apply not just to the woman herself, but also to relatives and friends who may accompany her to the health facility. Since antenatal care visits are generally planned, these costs can be prepared for. However, since the timing of the onset of labor is less predictable, the woman is more liable to finding herself unable to meet these other costs.[169,184,248]

One possible explanation for the inability of the NHIS to shift overall national trends in neonatal and infant mortality is its failure to achieve universal coverage. As earlier discussed, the NHIS has been unable to cover the majority of the Ghanaian population sources, [64,132] This in effect means that when the entire population is considered, any effect of the policy on its membership may be diluted by its lack of impact on non-enrolled. This begs the question of why we still saw an impact on antenatal coverage and skilled delivery. In interpreting those findings, it is worth noting that antenatal coverage is often delivered outside major health facilities—for example, through family planning clinics, community health centres, outreach programs and even home visits by community health workers. Care through these channels is often subsidized (and thus much more affordable even for the uninsured), and also seldom requires registration with the NHIS.[169,174,176]

With skilled attendance at birth, the advent of the NHIS by itself appears to have been inadequate to improve outcomes. It took the implementation of the Free Maternal Healthcare

program to shift the needle on this outcome. This may have to do with the fact that, unlike antenatal care, skilled attendance at birth requires that the woman travel to a health facility and consequently, the additional costs of accessing care (discussed previously) and requirements for registration and payment of premiums under the NHIS applied. The implementation of the FMH removed the latter two obstacles and thus greatly facilitated the use of skilled attendance at birth by all women, irrespective of NHIS coverage status.[183,250]

The socio-economic make up of those covered also suggests that enrollment into the NHIS has not been equitable. Its membership is decidedly skewed in favor of urban dwellers, the formally employed and better-educated—categories of people who had a considerable advantage in accessing health services even before the advent of the NHIS. Beyond its implications for equity in access to healthcare, this situation could potentially hinder the ability of the policy to impact overall population health outcomes as adverse health outcomes tend to be concentrated among the socio-economically disadvantaged.[42,134]

Another consideration that could help explain the concentration of impact of the policy on skilled attendance and antenatal care usage among the socio-economically advantaged are the cultural norms around seeking healthcare. Socio-cultural norms surrounding labor and womanhood are still prevalent in many parts of Ghana, especially in rural communities. Some women in these communities are not allowed to seek care without the consent of their spouses or other male relative, or sometimes their mother in law. The traditional value systems of these communities also promote home delivery as a mark of a woman's womanhood. These practices would tend to limit utilization of healthcare even when financial barriers are removed.[174,249,251,252]

While the introduction of the health insurance scheme has helped to remove demand-side barriers to healthcare utilization, it may have inadvertently created some supply-side impediments at the same time. As previously noted, the advent of the NHIS rapidly increased both access to healthcare as well as utilization. The patient burden on health facilities consequently increased substantially—in many instances beyond the design capacity of those facilities.[253] There is some evidence that this may have resulted in a deterioration in the quality of services provided in these facilities, as reflected in long wait times, and patient congestion. Over time, this may have contributed to the NHIS developing a reputation for providing poor quality services for its clients.[112,254] This is despite the fact that the advent of the NHIS may have positively impacted the supply-side of the healthcare equation as well. The policy has provided an assured (albeit often delayed) source of reimbursement for health providers, which together with the general increase in service utilization has resulted in an increase in revenue for many facilities.[253]

When considering the impact of the NHIS on early childhood mortality, it is worth noting that healthcare service utilization is only one contributor to health outcomes. Non-healthcare factors such as nutrition, sanitation, environmental factors and socio-cultural practices are important contributors to infant and neonatal mortality.[175,230,255] The lack of impact of the NHIS on early childhood mortality suggests that any shift in these outcomes due to the policy may not have been enough to overcome the contributions of these factors.

4.6.1 Strengths/limitations of the study

This study benefited from the availability of multiple DHS surveys allowing the construction of 10 years of pre-intervention data. This enabled us to model pre-intervention trends in the

outcomes and check for violations of the parallel trends assumption. While not a guarantee of the validity of the parallel trends assumption, the fact that we found little evidence to suggest that the assumption is violated in our data in the pre-intervention period increases our confidence in the validity of our findings. Having said this, we reiterate that the parallel trends assumption is by nature unverifiable and so, like all users of the difference-in-difference approach, we can only trust that the assumption holds in the post-intervention period.

As will all causal analyses, our results are dependent on the absence of unmeasured confounding. While the difference-in-difference approach theoretically reduces unmeasured time-stable confounding, we must still contend with potential time-varying confounding. In this case, such confounding could result for example, from changing macroeconomic trends that influence both the decision to implement a policy such as the NHIS, and at the same time affect the socio-economic circumstances of mothers in the countries in our sample.

Such changes could result for example from variations in government expenditure on health over the study period. Government investment in expanding health infrastructure and resources, especially in rural areas could have contributed to improving access to healthcare, healthcare utilization and possibly health outcomes independent of the NHIS policy. As this work does not incorporate information on such expenditures, it is unable to exclude their contributions to any observed effect and these contributions would be inadvertently attributed to the NHIS policy.

This study explored both intermediate and distal health outcomes and thus can provide a fairly comprehensive picture of the impact of the NHIS policy on the health of the population. Also, in

this study, we considered the effect of the policy on the entire population of Ghana and not just those insured. This allows us to account for spillover and indirect effects of the policy beyond its impact on its own membership. This gives a more complete view of the impact of the policy across the country over the study period.

This study shares the limitations of all studies based on survey data. It is prone to sampling (related to selection), and content (related to responses) errors. In particular, when dealing with data which requires the recall of event dates, there is a tendency towards "heaping" of responses around round figures, even number, and multiples of five and 10. This phenomenon has been well documented in DHS data and would tend to a misclassification of our outcomes.[188,256,257] However, we have no reason to expect this phenomenon to be substantially differential in occurrence between our treatment and control groups and so would expect the net impact on our effect estimates to negligible. Another source of potential outcome misclassification derives from a tendency of mothers whose children died recently to remember their dates of death more accurately compared to those whose children died more distantly. Again, this phenomenon should not act differentially and would be expected to have a negligible effect on our results.

4.7 Conclusion

We examined the impact of the NHIS on healthcare utilization and early childhood mortality outcomes for the entire population of Ghana. We found that while antenatal care usage and skilled attendance had been positively impacted, neonatal and infant mortality remained largely unaffected by the policy. Our study suggests that the NHIS may not be meeting its goal of ensuring access to, and utilization of healthcare services by all residents of Ghana and may have not yet produced actual benefit in terms of improved health outcomes for the population as a

whole. Our findings suggest that there is a need for further research to reexamine the policy with the improvement of health outcomes for the entire population in mind. Operationally, more needs to be done by the managers of the NHIS to improve coverage in general and for the disadvantaged in society in particular under the scheme.

5 IMPACT OF NHIS ON RURAL-URBAN DIFFERENCES IN NEONATAL AND INFANT MORTALITY

5.1 Preface

One of the expressed goals of UHC reforms such as the NHIS is achieving equity in health utilization and outcomes.[44] This ideally implies improving the lot of the disadvantaged without making anyone else worse off. One of the strata that is of particular interest when discussing issues around health equity in low- and middle-income countries is rural-urban residence.

Rural dwellers tend to be distinct from urban dwellers in many important respects. They are often less wealthy, less educated and often work in agriculture.[100,241] Rural communities themselves are also quite distinct from urban ones, often by being considerably less well served by public infrastructure and services. This disadvantage runs the gamut from basic services such as transportation, potable water and electricity, to modern technologies like mobile telephone coverage and internet. In health as well, rural dwellers tend to be much worse off[111,258,259].

The availability of health resources in rural areas is often below the average for urban areas. In many low- and middle-income countries like Ghana, most trained health professionals ply their trade in the cities. Available health facilities in rural areas are often far from most people's homes and generally not as well equipped as those in urban areas. Rural dwellers who need specialized care often face the prospect of making a major trip to the city with its attendant costs.[124,125,260,261] Worsening the situation is the fact that partly consequent on their socio-economic disadvantage, rural dwellers tend to suffer poorer health and thus have a greater need or access to health services.[49,262,263]

It is thus not surprising that a considerable gradient exists in many health outcomes between rural and urban dwellers to the disadvantage of the former. [49,264] This disadvantage is also seen in early childhood mortality, not just in Ghana, but in many low- and middle-income countries.[49,264]

But perhaps most importantly for this paper, by virtue of being poorer, rural dwellers tend to suffer the worst when healthcare is unaffordable—such as it was under the fee-for-service regime that was replaced by the NHIS. Thus, at the dawn of the NHIS, there was a considerable pool of underserved people needing healthcare in rural areas. It is thus conceivable that as healthcare was made affordable, these would be able to obtain healthcare and we would see improved outcomes.[42] We have reason to believe, however that coverage under the NHIS has tended to favor urban dwellers.[2] Thus, it is unclear whether the NHIS has mitigated, exacerbated or been neutral concerning rural-urban inequalities in health.

In this second paper, I attempt to answer this question by examining trends in early childhood mortality over time. This approach allows me to examine not just whether the introduction of the NHIS has influenced the magnitude of rural-urban differences in infant mortality, but how these inequalities have evolved over time, prior to and after the NHIS.

I conceived this study under the guidance of Drs. Kaufman and Nandi. I conducted the analysis and wrote the manuscript. The manuscript was reviewed by Drs. Kaufman and Nandi and their comments were incorporated into the final version.

5.2 Abstract

Background: One of the key aims of the National Health Insurance Scheme of Ghana (NHIS) is to improve equity in health outcomes. While the NHIS has been shown to improve health utilization for its members, it is not clear that this has translated into equity in health outcomes across socio-economic strata. We assessed the impact of the NHIS on levels and trends in neonatal and infant mortality across strata of rural-urban residence.

Data and methods: We assembled a sample of births from 1993 to 2013 from the Demographic and Health Surveys for Ghana and applied an interrupted time series analytic approach to examine levels and trends in neonatal and infant mortality before and after the implementation of the NHIS.

Results: We found a pre-NHIS rural-urban disparity in infant mortality of 13.3 [6.4, 20.8] deaths per 1000 live births to the disadvantage of rural dwellers and this decreased by -17.5 [-28.8, -5.8] deaths per 1000 live births with the advent of the NHIS. We found an ongoing decreasing trend in rural infant mortality of -4.4 [-7.8, -0.3] deaths per 1000 live births per year. We found no evidence of either a pre- or post-NHIS difference in levels or trends in neonatal mortality between rural and urban dwellers. Our findings were robust to adjustment for socio-economic variables such as a household wealth and maternal education.

Conclusion: We found evidence that the advent of the NHIS improved rural-urban differences in infant mortality both via a narrowing of the rural-urban difference in levels of this outcome in the immediate post-intervention period and also via a continuing decreasing trend in mortality for rural dwellers in the post-intervention period. We found no evidence that neonatal mortality was

affected by the policy. Thus, the NHIS appears to be on track to achieve its equity goals for infant mortality

5.3 Introduction

We assessed the impact of the National Health Insurance Scheme of Ghana on rural-urban differences in the levels and trends of early childhood mortality. Like all Universal Health Coverage (UHC) reforms, one of the key goals of the NHIS is to achieve equity in health outcomes. It aims to remove financial barriers to accessing healthcare and thus ultimately achieve improved health outcomes for the entire population of the country irrespective of socio-economic circumstances.[75]

Survival in the first year of life has generally improved in Ghana over the past 30 years. Infant mortality has seen a steady sustained decline over the period, decreasing by about 1% per year. The estimated infant mortality rate for children born in 2008, was about 52 per 1000 live births .[227] Neonatal mortality has also seen some improvement, although this progress appears to have stalled somewhat in the past decade [227]. The WHO estimates the neonatal mortality rate in Ghana in 2006 was 27 per 1000 live births.[226] It is unclear that people of all socio-economic classes have benefited equally from these gains. In particular rural dwellers have been known to suffer poorer health outcomes compared to their urban counterparts.[69]

The rural disadvantage in health outcomes has been attributed in part to the socio-economic advantage that urban dwellers enjoy. Being wealthier and better educated means urban dwellers are generally healthier to begin with. This advantage is further enhanced by the fact that urban dwellers enjoy better access to care, and consequently use more healthcare compared to their rural counterparts. One of the majors factor driving this historical inequality in healthcare utilization between rural and urban dwellers has been affordability of care.[141,173]

The NHIS was established in 2003 to ameliorate disparities in access to healthcare by making healthcare services affordable for all.[46] It replaced the then existing fee-for-service payment system commonly dubbed "cash-and-carry," which was blamed for excluding the socioeconomically disadvantaged from accessing healthcare. In addition to enhancing equity in access to healthcare, the NHIS aims to reduce out-of-pocket health expenditures for households.[41,45]

The NHIS is mostly funded through a value added tax on goods and services but requires that beneficiaries register and pay annual premiums. These premiums were initially meant to be graduated according to income, with exemptions for various identified vulnerable groups, but this has proven difficult in practice.[48]

The most direct impact of the NHIS so far appears to have been on levels of healthcare utilization. Women enrolled in the NHIS have been shown to make more antenatal care visits compared with those not enrolled.[148] Those insured under the scheme have been found to be more likely to seek healthcare when ill rather than self-medicate,[149,150] as opposed to the uninsured who tend to seek healthcare mainly for critical conditions.[142] The higher levels of healthcare utilization among the insured compared to uninsured has been found to persist even when issues of self-selection are taken into account.[63] These findings are reinforced by the findings of the first manuscript of this thesis (chapter 4).

Despite these gains, it is unclear that the NHIS is achieving its equity goal. Prior to the NHIS, those with greater wealth and higher education were more likely to use healthcare services, such as attending antenatal care clinics. This same demographic has been found to be more likely to be registered and retained in membership of the NHIS, thus accruing more of its positive impact.

Some studies have actually found that access to healthcare for the uninsured may have worsened with advent of the NHIS.[48]

Rural dwellers have been found to be much less likely to be covered compared to urban dwellers. A study conducted four years after the implementation of the NHIS found that fewer than 40% of households in a rural district were covered.[132] With such low levels of coverage in rural areas, it would not be surprising to find they have lower levels of healthcare utilization and consequently poorer health outcomes as well. Further potentially worsening outcomes for rural dwellers is the fact that their economic disadvantage which we describe above is a predictor of poorer health independent of healthcare utilization. This is not helped by their poorer availability of healthcare services in rural areas.[263,265,266]

The question of the impact of the NHIS on equity in health outcomes remains incompletely answered in two respects. Firstly, the impact of the policy on equity in non-health-service outcomes is not fully understood, and secondly, those studies that have considered the equity dimensions of the NHIS's impact have generally compared outcomes among those covered by the policy to those not covered, or studied these outcomes within specific sub-populations, thus leaving questions of the population-level effects of the policy on equity unanswered.[46,75,144,154,267] Considering the low levels of coverage of the policy, especially among rural dwellers,[74,268] these approaches tend to give an incomplete picture of the impact of the policy as a whole.

In this study, we contribute to remedying these gaps in the literature by exploring changes in levels and trends in neonatal and infant mortality, comparing rural and urban dwellers from the pre-NHIS to post-NHIS period.

5.4 Methods

5.4.1 General approach to the analysis

We used an interrupted time series (ITS) approach to examine the impact of the NHIS on trends in rural-urban differences in mortality, allowing for the policy to have both an immediate effect on the level of the rural-urban inequality, as well as a persistent effect on the rural-urban inequality over time. The ITS study design uses predicted post-intervention trends as counterfactuals for their corresponding observed post-intervention trends. The estimate of effect is obtained by comparing the two on an appropriate scale.[87]

In the basic ITS design, the post-intervention counterfactual trend is obtained by extrapolating the observed pre-intervention outcome trend into the post-intervention period. This method has the advantage of being able to describe the effect of an intervention in terms of a functional form that is fit to the data. It can be used to capture linear and non-linear trends with varying gradients across intervention groups, as well as incorporating temporary and persistent changes in level of the outcome.[198,201]

The method is typically used for causal inference in situations where we have enough pre-intervention data to accurately model the pre-intervention trend, and no control group to use to model the counterfactual outcome for the intervention group. The basic design can however be extended with the inclusion of a control group to address threats to internal validity, (such as historical changes in the methods of assessment of the outcome and time-varying factors affecting the outcome).[86]

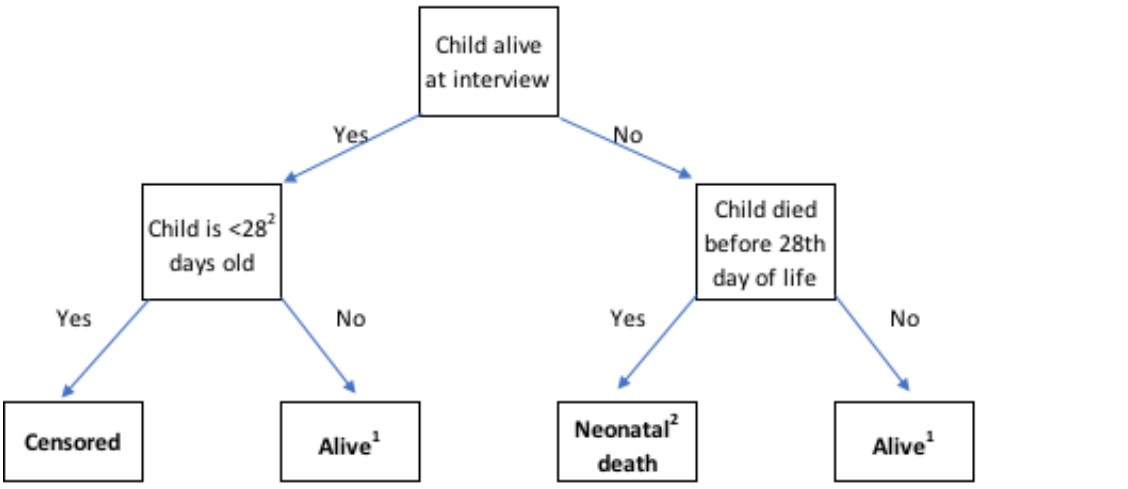
5.4.2 Data

Our population of interest was children born in Ghana between 1993 and 2013. We used data from the International Public Use Microdata Series versions of the Demographic and Health Surveys (IPUMS-DHS)[187] for Ghana for 1993, 1998, 2003, 2008 and 2014. The Demographic and Health Surveys (DHS) are a series of nationally representative multi-stage-sampled surveys which collect data on fertility, family planning and health outcomes, among other characteristics. The IPUMS-DHS versions of the DHS datasets contain variables and weights which have been harmonized across surveys to facilitate the pooling of data.

In the DHS surveys for Ghana, a multi-stage sampling procedure is used in which randomly selected households (the secondary sampling units) are chosen from a sample of census enumeration areas (the primary sampling units), which are themselves selected using a probability proportional to size sampling method from a listing of census enumeration areas. Data are then collected on all births to women of reproductive age (15 to 45 years) in these households.

5.4.3 Study design

We assembled separate samples of births by quarter of birth, for each outcome using birth records from 1993 to 2013. The criterion for inclusion in any of the samples was being born in Ghana between 1993 and 2013. For our neonatal mortality sample, we excluded all births which occurred within 28 days of the mother being interviewed; likewise, we excluded all births within 12 months of the mother's interview date for our infant mortality sample.



Note:
[1] Indicates that child is counted as alive at end of follow-up period for the purposes of analysis
[2] Similar flow chart applies to infant mortality with 12 months as the threshold period instead of 28 days

Figure 5-1: Sample selection and outcome classification for neonatal mortality

By excluding children whose outcomes (either neonatal or infant death/survival) were unobserved because they had not yet reached the relevant threshold ages (28 days for neonatal mortality and 12 months for infant mortality), we created samples with complete follow-up for all subjects for the full study period. A schematic of the procedure for determining the outcome status of subjects and assembling the samples is presented in Figure 5.1.

5.4.4 Measures

We examined two outcomes: neonatal mortality, defined as the death of a child within 28 days of birth, and infant mortality, defined as the death of a child within 12 months of birth.

Our exposure was an indicator of being born after the implementation of the NHIS in Ghana (0 = born before NHIS, 1 = born after NHIS). We explored rural-urban differences in our outcomes

within each birth sample, and for this purpose we used the DHS designation of rural-urban area (coded 1 for urban and 0 for rural). The DHS designation is itself based on the population-size-based classification used in the Ghana Population and Housing Census.[269]

In the evaluation of health equity, a distinction is sometimes made between inequalities and inequities. Inequities are derived from inequalities when ethical judgements of fairness are applied to the evaluation of those inequalities. In such cases, the influence of factors whose contribution to inequalities is deemed "fair" is removed, usually through adjustment or standardization or some other form of weighting. The judgement of a factor's fairness is generally based on subject matter considerations rather than statistical reasoning.[270,271]

In this study, we conducted our analyses both unadjusted and adjusted for socio-economic status (SES). In adjusting for SES, while adjusting for SES in this manner implicitly assumes that any variation in our outcomes due to SES is "fair", we do not explicitly make that claim as our interest in doing so is primarily to account for any time trends in SES which could influence our results. Also, some authors distinguish between inequalities and disparities in outcomes—for the purposes of this paper, we will use these words interchangeably.

To this end, we defined two measures of SES: household wealth measured as quintiles of a score derived as predictions from a principal-components analysis of household assets such as bicycles, televisions and telephones, and maternal education measured as an indicator of the level of education completed by the mother.

5.4.5 Statistical analysis

5.4.5.1 Estimation of quarterly mortality rates

Our evaluation of levels and trends in rural-urban differences in neonatal and infant mortality proceeded as follows. We first estimated the neonatal and infant mortality rates by quarter of birth (defined by calendar month, with the first days of January, April, July and October as the first days of the corresponding quarters) for Ghana within each birth year. We did this by fitting weighted logistic regression models of the form:

Equation: 14: $$logit(Y_{it}) = \partial_0 + \partial_1 U_{it} + \boldsymbol{\vartheta Q_i'} + \boldsymbol{\theta}(\boldsymbol{UQ})_i{}' + \boldsymbol{\phi C'} + \varepsilon_i$$

Where:

- Y_{it} is the quarterly death count (either neonatal or infant death)
- U_i is an indicator of urban/rural residence
- $\boldsymbol{Q'}$ is a vector of indicators of quarter of birth with $\boldsymbol{\vartheta}$ as the vector of their corresponding coefficients
- $\boldsymbol{UQ}$ is a vector of interaction terms between each quarter of birth and urban/rural residence with $\boldsymbol{\theta}$ as the vector of their corresponding coefficients
- $\boldsymbol{C'}$ is a vector of covariates with $\boldsymbol{\phi}$ being the vector of corresponding coefficients
- ε_i is an error term

The vector of coefficients $\boldsymbol{C'}$ was chosen to reflect ethical considerations. Specifically, we sought to eliminate the contribution of socio-economic factors to any observed effects. In doing this, we evoked the mandate of the NHIS to improve access to healthcare for all residents of Ghana irrespective of socio-economic circumstances.

The weights in our models were obtained from applying the DHS-recommended denormalization procedure to the person-weights from the DHS samples. This involves adjusting these weights for the sampling fraction for women aged 15 to 45 years (child-bearing age). i.e.

Equation: 15: $$W_{ict} = \frac{n_{ct}}{P_{ct}} * w_i$$

Where

n_{ct} is the number of women aged 15 – 45 years interviewed in country c in survey year *t,*
P_{ct} is the population of females aged 15 – 45 years in country c in survey year *t*. w_i is the individual sample weight for each woman *i* interviewed.

We fitted these models on the data in our neonatal and infant mortality samples. From these models, we estimated the neonatal and infant mortality rates for each quarter within each birth sample separately for rural and urban dwellers. We thus obtained a time-series dataset with quarterly neonatal and infant mortality outcomes by urban/rural residence.

5.4.5.2 Pre-specified model

The interrupted time series analysis method requires the a-priori specification of a functional form for the trends in the outcome, if valid inferences are to be made from the model.[272] In this study, we specified a main model impact model that allows for rural-urban differences in outcome levels at baseline, linear pre-intervention trends in the outcome, jumps in outcome levels immediately after the intervention, and linear post-intervention trends in the outcome.

The specification of our main model was based on the following argument: The fee-for-service system that existed before the introduction of the NHIS favored people of higher socioeconomic status with the capacity to pay out of pocket, and thus limited access to healthcare services among rural dwellers compared to urban dwellers.[42] Rural areas in Ghana are also generally underserved, in terms of health infrastructure and resources, compared with urban areas.[141,184]

We hypothesized that these factors would cause the slopes of the trends in neonatal and infant mortality in rural areas to differ from urban areas in the pre-intervention period. Specifically, we expected a steeper slope of decline in mortality rates for urban dwellers compared to rural dwellers. The introduction of the NHIS removed financial barriers to access to care for a considerable portion of the population. Since a larger proportion of the rural population were underserved pre-intervention, we expected a greater initial impact of the policy on rural compared to urban dwellers. This would manifest as a bigger drop in mortality rates among rural dwellers compared to urban dwellers in the immediate post-intervention period.

We posited that the slopes of the mortality rates in both rural and urban areas would decrease further in the post-intervention period, indicating that the mortality rates continued to decrease over time, as more and more people gained access to, and utilized health services. Due to pre-existing differences in capacity and investment in the development of healthcare resources, we expected the change in the slopes of the trends to differ between urban and rural areas, though we could not predict a-priori which would see the greater change. Our pre-specified main model was a Poisson model of the form:

Equation: 16: $$\log(Y_{ut}) = \beta_0 + \beta_1 U_t + \beta_2 T + \beta_3 P_t + \beta_4 (U_t * P_t) + \beta_5 (U_t * T) + \beta_6 (P_t * T) + \beta_7 (U_t * P_t * T) + \boldsymbol{\theta Q'} + \varepsilon_t$$

where

- Y_{ut} is the outcome (either quarterly neonatal mortality or quarterly infant mortality rate) at time t
- U_t is an indicator of rural/urban residence (0 = rural, 1 = urban) at time t
- T is the quarter of birth measured as a continuous variable
- P_t is an indicator of being born in the post intervention period (coded 0 = no, 1 = yes)
- $\boldsymbol{Q'}$ is a vector of indicators of quarter of birth (coded 1-4) with $\boldsymbol{\theta}$ being a vector of their corresponding coefficients

From this model, the baseline level of the outcome among rural dwellers would be β_0 and this would change by β_3 after the intervention. The estimated baseline rural-urban disparity in the outcome would be β_1, and this would change by β_4 after the policy takes effect. The slope of the pre-intervention linear trend in the outcome among rural dwellers would be β_2 and would change by β_6 in the post-intervention period. The pre-intervention rural-urban disparity in the slope of the trend in outcomes would be β_5 and this would change by β_7 in the post-intervention period.

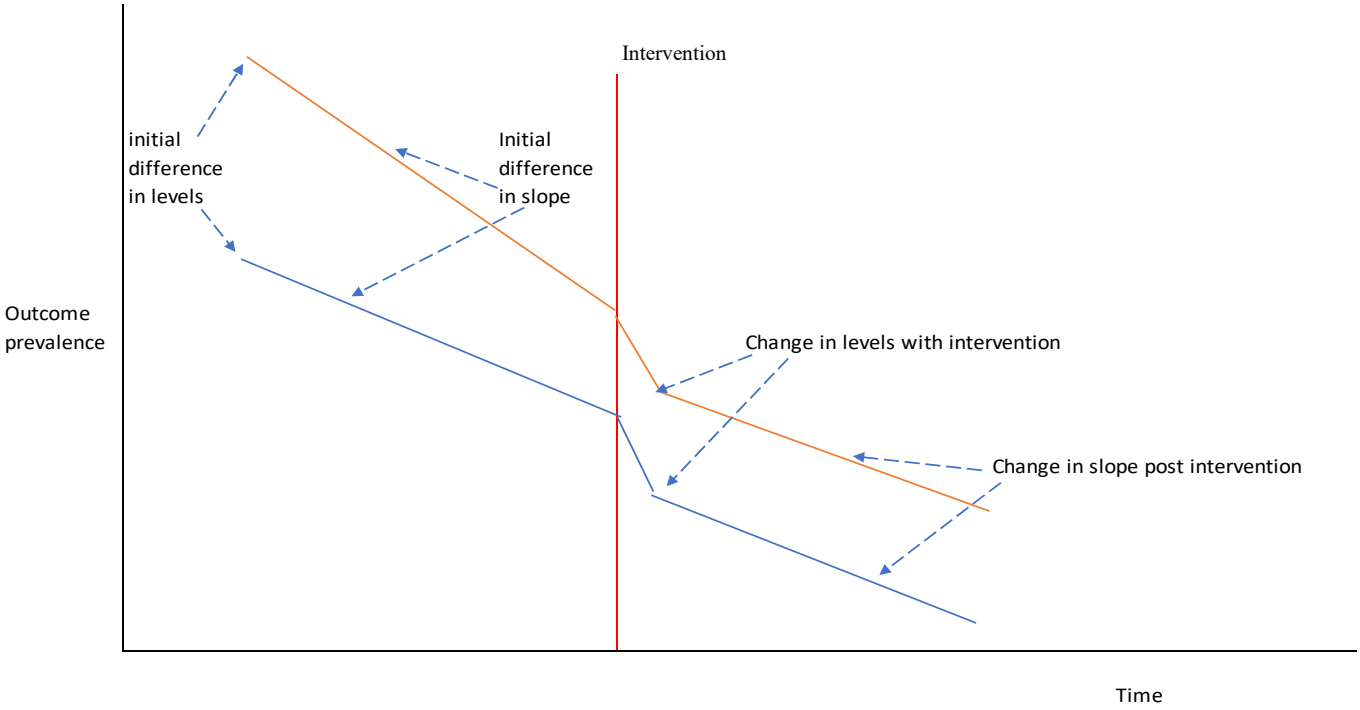


Figure 5-2: Simplified representation of ITS model

5.4.5.3 Assessing model fit and performance: stationarity, overdispersion, serial autocorrelation

To be able to make accurate predictions from time series data, they must stationary—i.e. the mean and variance of the data must remain constant with time. In our specific case, stationarity implies that the mean and variance of our model errors remain constant over time. A number of tests have been devised to check for stationarity. These range from a visual inspection of the

distribution of model errors over time to tests for a unit root such as the Dickey-Fuller (DF) test which we used in this instance. This is a test of the null hypothesis that a unit root is present in an autoregressive model, with the alternative being either the existence of stationarity or trend-stationarity. [273–275]

Poisson models assume that the variance and mean of the data they are fit to are the same. When the variance of the data distribution considerably exceeds the mean of the data, we have overdispersion. Overdispersion is a phenomenon that is observed with discrete data and, which in the context of a generalized linear model, manifests as the mean and variance components being related, and both dependent on a parameter that is predicted by the vector of independent covariates. To account for overdispersion in our data, we set our scale parameter to the ratio of the Pearson-chi-squared statistic to the residual degrees of freedom as recommended in McCullagh et al (1990).[276]

The Poisson regression model we fit to our data assumes our observations are independently and identically distributed—yielding model residuals which are uncorrelated. In time series data, however, this assumption may be violated as the time-order of the data often matters. Observations closer in time tend to be more correlated with each other than those further apart (temporal/serial autocorrelation). Time series analysis requires that this correlation is accounted for in order to make valid inferences and predictions.

Temporal autocorrelation is often assessed by examining the autocorrelation function (ACF), which looks at the correlation between each time point and all time points before it, and the partial autocorrelation function (PACF), which assesses the correlation between any two time points, excluding the contribution of intervening time points. The patterns of autocorrelation and

partial autocorrelation across all time points is used to diagnose the presence, type (whether autoregressive or moving average or both) and extent of autocorrelation present. Further discussion of this can be found in Meyer et. al (2006).[201] The autocorrelation may be modelled by regressing the outcome at each time point on the values of the outcome at previous time-points (autoregressive models), allowing the errors for the model at any time to be correlated with errors at a past time point (moving average models) or a combination of the two (ARMA, ARIMA, ARIMAX etc.)

For our ITSA models, our approach to assessing and handling potential autocorrelation was as follows: We first fit our pre-specified model to our data and generated predicted errors for each observation. We then assessed temporal autocorrelation within the model errors. We next fitted an updated model with either autoregressive or moving average terms to account for any autocorrelation found in the residuals. In the absence of evidence of autocorrelation among the residuals, we fit our pre-specified model and estimated standard errors by non-parametric bootstrapping.[277,278]

Another factor one needs to consider when doing ITS analysis is seasonality. This refers to the correlation between time points separated by regular intervals. We assessed this, as with autocorrelation, by examining the ACF and PACF functions. We conducted our analyses in STATA version 13.[204,247]

5.5 Results

Table 5-1: Demographic and socio-economic characteristics of study sample

	Urban N=13,622	Rural N=27,056	Total N=40,678
Demographic characteristics	n (%)	n (%)	n (%)
Maternal age at birth			
< 19 yrs	1,257 (9.2)	2,761 (10.2)	4,018 (9.9)
20 – 24 yrs	3,411 (25.0)	6,985 (25.8)	10,396 (25.6)
25 – 29 yrs	4,034 (29.6)	7,113 (26.3)	11,147 (27.4)
30 – 34 yrs	2,976 (21.8)	5,416 (20.0)	8,392 (20.6)
>35 yrs	1,944 (14.3)	4,781 (17.7)	6,725 (16.5)
Maternal education level			
None	3,550 (26.1)	14,397 (53.2)	17,947 (44.1)
Primary	2,749 (20.2)	5,853 (21.6)	8,602 (21.1)
Secondary or higher	7,323 (53.8)	6,806 (25.2)	14,129 (34.7)
Household wealth			
Poorest	860 (6.3)	12,389 (45.8)	13,249 (32.6)
Poor	1,161 (8.5)	8,055 (29.8)	9,216 (22.7)
Middle	2,926 (21.5)	4,607 (17.0)	7,533 (18.5)
Rich	4,346 (31.9)	1,622 (6.0)	5,968 (14.7)
Richest	4,329 (31.8)	383 (1.4)	4,712 (11.6)
Outcomes			
Neonatal deaths			
Pre-intevention period	306 (3.5)	735 (3.8)	1,041 (3.7)
Post-intervention period	161 (3.4)	219 (2.9)	380 (3.1)
In first baseline study year (1993)	43 (5.1)	99 (4.8)	142 (4.9)
In intervention year (2003)	25 (3.8)	57 (4.5)	82 (4.3)
In last post-interv study year (2013)	10 (2.1)	15 (2.1)	25 (2.1)
Infant deaths			
Pre-intevention period	432 (5.2)	1,176 (6.6)	1,608 (6.2)
Post-intervention period	241 (5.4)	348 (4.9)	589 (5.1)
In first baseline study year (1993)	47 (7.1)	119 (7.8)	166 (7.6)
In intervention year (2003)	22 (4.3)	56 (6.7)	78 (5.8)
In last post-interv study year (2013)	14 (3.5)	15 (2.5)	29 (2.9)

We started with 40,678 children born in Ghana between 1993 and 2013 who were captured in the DHS births dataset. From this, we excluded 117 children born less than a month before their mothers were interviewed, for our neonatal sample. Similarly, for our infant mortality sample, we excluded 3,055 children who were born less than 12 months before their mothers were interviewed.

Table 5-2: Changes in rural and urban levels and trends in neonatal mortality in Ghana from 1993 to 2003 allowing for the impact of the National Health Insurance Scheme

	Unadjusted Model	Adjusted Models		
		Wealth	Maternal Education	Fully Adjusted
Pre-NHIS rural baseline level	28.9 [22.0, 37.7]	28.9 [21.8, 38.5]	28.8 [21.7, 38.4]	28.9 [21.7, 38.4]
Pre-NHIS urban baseline level	39.9 [27.0, 62.0]	40.0 [27.0, 59.2]	39.7 [26.8, 58.9]	39.8 [26.9, 59.0]
Pre-NHIS rural-urban disparity in levels	2.6 [-2.9, 8.0]	2.6 [-3.5, 7.9]	2.3 [-3.8, 7.6]	2.3 [-3.8, 7.6]
Post-NHIS rural level	37.4 [28.5, 49.2]	37.4 [28.9, 48.6]	36.9 [28.5, 47.9]	36.9 [28.5, 48.0]
Post-NHIS urban level	33.4 [23.1, 45.8]	33.4 [23.0, 45.0]	32.9 [22.6, 44.4]	33.0 [22.7, 44.5]
Post-NHIS rural-urban disparity in levels	-6.0 [-13.2, 1.7]	-6.0 [-12.8, 1.8]	-6.1 [-12.8, 1.6]	-6.1 [-12.8, 1.7]
Pre-NHIS rural baseline trend	-2.8 [-5.7, 0.4]	-2.8 [-5.6, 0.3]	-2.8 [-5.6, 0.3]	-2.8 [-5.6, 0.3]
Pre-NHIS urban baseline trend	0.0 [-3.3, 3.2]	-0.1 [-3.2, 3.1]	-0.1 [-3.2, 3.0]	-0.1 [-3.3, 3.0]
Pre-NHIS rural-urban disparity in trends	2.7 [-1.4, 7.1]	2.7 [-1.2, 6.8]	2.7 [-1.2, 6.7]	2.7 [-1.2, 6.8]
Post-NHIS rural trend	-1.8 [-5.2, 1.8]	-1.8 [-5.1, 2.0]	-1.8 [-5.1, 1.9]	-1.8 [-5.1, 1.9]
Post-NHIS urban trend	-1.6 [-4.4, 2.4]	-1.6 [-4.2, 2.7]	-1.5 [-4.2, 2.6]	-1.5 [-4.2, 2.7]
Post-NHIS rural-urban disparity in trends	0.2 [-3.9, 5.7]	0.2 [-3.2, 5.8]	0.2 [-3.2, 5.7]	0.3 [-3.1, 5.8]
Difference in rural-urban disparities in levels from pre-NHIS to post-NHIS	-8.6 [-17.8, 0.8]	-8.6 [-17.6, 1.6]	-8.4 [-17.3, 1.8]	-8.4 [-17.3, 1.9]
Difference in rural-urban disparities in trends from pre-NHIS to post-NHIS	-2.5 [-8.8, 4.1]	-2.6 [-8.4, 4.2]	-2.5 [-8.2, 4.2]	-2.5 [-8.2, 4.3]

Note:
Levels and disparities in levels are measured in deaths per 1000 live births
Slopes and disparities in slopes are measured in deaths per 1000 live births per year

Table 5-3: Changes in rural and urban levels and trends in infant mortality in Ghana from 1993 to 2003 allowing for the impact of the National Health Insurance Scheme

	Unadjusted Model	Adjusted Models		
		Wealth	Maternal Education	Fully Adjusted
Pre-NHIS rural baseline level	45.3 [36.7, 54.7]	45.6 [37.2, 55.0]	45.4 [37.0, 54.9]	45.7 [37.2, 55.1]
Pre-NHIS urban baseline level	54.7 [38.6, 84.7]	55.3 [39.4, 85.2]	55.0 [39.1, 84.8]	55.4 [39.4, 85.4]
Pre-NHIS rural-urban disparity in levels	13.3 [6.4, 20.8]	13.6 [6.5, 21.1]	13.0 [6.0, 20.4]	13.0 [5.9, 20.5]
Post-NHIS rural level	58.6 [48.8, 68.1]	59.2 [49.9, 68.8]	58.3 [49.3, 67.8]	58.6 [49.3, 68.1]
Post-NHIS urban level	60.5 [47.7, 81.4]	61.2 [46.8, 80.2]	60.2 [46.1, 78.9]	60.5 [46.4, 79.5]
Post-NHIS rural-urban disparity in levels	-4.1 [-12.7, 5.5]	-4.1 [-12.5, 5.9]	-4.6 [-12.9, 5.3]	-4.6 [-13.0, 5.3]
Pre-NHIS rural baseline trend	-2.7 [-6.5, 1.0]	-2.7 [-6.5, 1.1]	-2.7 [-6.4, 1.0]	-2.7 [-6.5, 1.0]
Pre-NHIS urban baseline trend	-2.7 [-6.7, 0.8]	-2.7 [-6.6, 0.8]	-2.7 [-6.5, 0.8]	-2.7 [-6.6, 0.8]
Pre-NHIS rural-urban disparity in trends	0.1 [-5.7, 5.2]	0.1 [-5.1, 5.1]	0.0 [-5.0, 5.0]	0.0 [-5.1, 5.1]
Post-NHIS rural trend	-1.7 [-7.3, 3.3]	-1.7 [-7.0, 3.3]	-1.7 [-6.9, 3.3]	-1.7 [-7.0, 3.3]
Post-NHIS urban trend	-4.4 [-7.8, -0.3]	-4.4 [-7.7, 0.2]	-4.3 [-7.6, 0.2]	-4.4 [-7.7, 0.2]
Post-NHIS rural-urban disparity in trends	-2.7 [-7.9, 4.0]	-2.7 [-7.6, 3.9]	-2.6 [-7.5, 3.9]	-2.6 [-7.5, 3.9]
Difference in rural-urban disparities in levels from pre-NHIS to post-NHIS	-17.5 [-28.8, -5.8]	-17.7 [-28.7, -4.6]	-17.6 [-28.5, -4.7]	-17.7 [-28.6, -4.7]
Difference in rural-urban disparities in trends from pre-NHIS to post-NHIS	-2.7 [-10.4, 5.6]	-2.7 [-10.2, 5.8]	-2.7 [-10.1, 5.8]	-2.6 [-10.0, 5.8]

Note:
Levels and disparities in levels are measured in deaths per 1000 live births
Slopes and disparities in slopes are measured in deaths per 1000 live births per year

Descriptive statistics for our study sample are given in Table 5.1 below. The distribution of maternal age at birth was similar for urban and rural mothers in our sample. Consistent with the distribution of socio-economic characteristics in the larger Ghanaian population, our sample shows urban dwellers having much higher levels of maternal education and household wealth compared to their rural counterparts.[279,280] The estimated levels and trends of neonatal mortality in Ghana over the study period are presented in Table 5.2 and in Figure 5.2 below.

Our results from the DF tests and our ACF and PACF plots suggest we had stationary trends with little evidence of temporal autocorrelation (Figures 5.3 and 5.4).

We present the results from our primary ITS analyses in Tables 5.2 and 5.3. From our fitted models, We found a rural-urban difference in neonatal mortality of 2.6 [-2.9, 8.0] deaths per 1000 LB at baseline and -6.0 [-13.2, 1.7] deaths per 1000 LB in the post-intervention period, representing a change of -8.6 [-17.8, 0.8] deaths per 1000 LB in the rural-urban inequality in neonatal mortality due to the advent of the policy.

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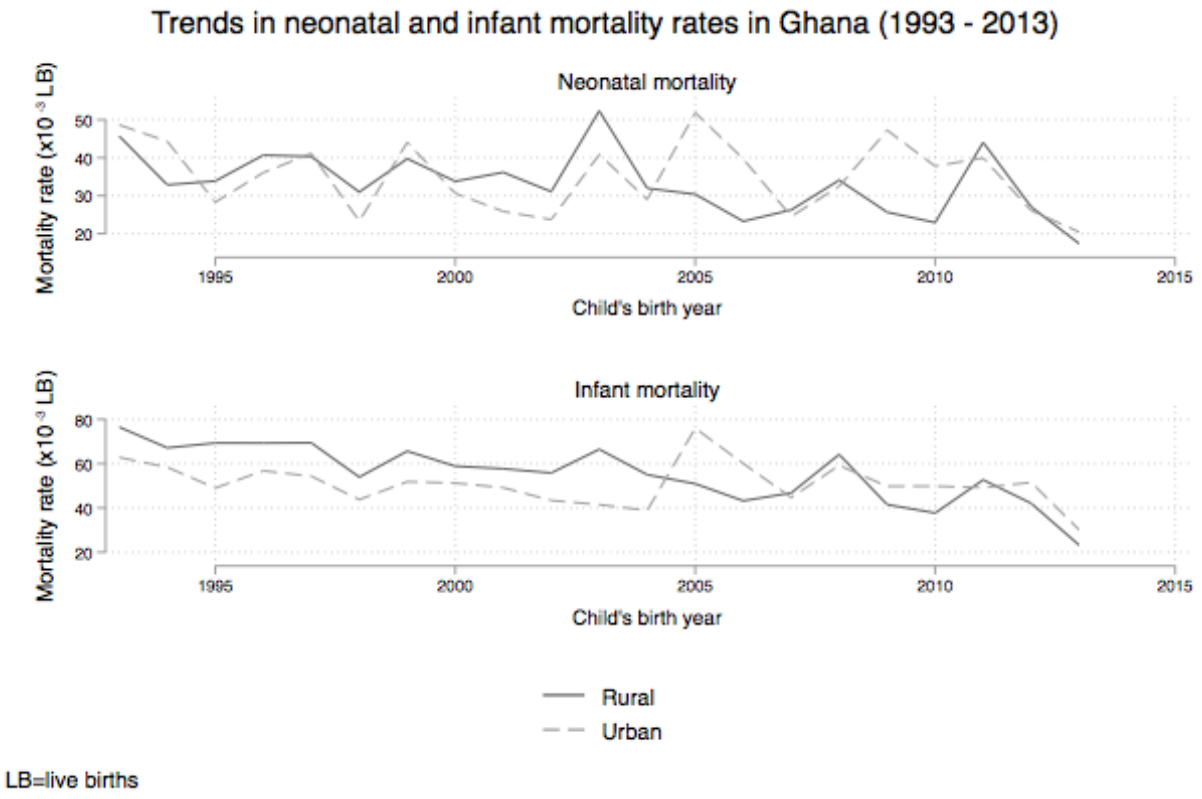


Figure 5-3Figure 5 3 Trends in neonatal and infant mortality rates for rural and urban dwellers in Ghana from 1993

The rural-urban difference in infant mortality rates was 13.3 [6.4, 20.8] per 1000 LB in the pre-intervention period and -4.1 [-12.7, 5.5] infant deaths per 1000 LB in the post-intervention period, representing a narrowing of the rural-urban difference in levels of infant mortality by -17.5 [-28.8, -5.8] deaths per 1000 LB with the implementation of the NHIS policy.

The rural-urban difference in the slopes of the trends in neonatal mortality was 2.7 [-1.4, 7.1] deaths per 1000 LB per year for the pre-intervention period and 0.2 [-3.9, 5.7] deaths per 1000 LB per year for the post-intervention period equivalent to a change of -2.5 [-8.8, 4.1] deaths per 1000 LB per year following the policy change.

In the pre-intervention period, the difference in the slope of infant mortality between rural and urban-born children was 0.1 [-5.7, 5.2] per 1000 LB per year in the pre intervention period. In the post-intervention period, we estimated the equivalent measure to be -2.7 [-7.9, 4.0] deaths per 1000 LB per year.

Adjusting for SES and maternal age at birth appears to have made little difference to our point estimates though our 95% confidence intervals tended to get wider.

5.6 Discussion

Our findings suggest that the implementation of the NHIS policy narrowed the rural-urban gap in infant mortality, mostly via a decrease in rural infant mortality in the post-implementation period. We found little evidence that the policy had discernibly affected rural-urban differences in neonatal mortality—either by altering levels of mortality or by changing ongoing trends in mortality. Those effects we found evidence for appear to have occurred without regard to

ongoing changes in SES. Our evidence suggests that the NHIS may be achieving its equity goals for infant mortality while equity in neonatal mortality remains yet unaffected.

As the NHIS remains one of the few examples of comprehensive nation-wide social health insurance reform in sub-Saharan Africa, its positive impact on rural-urban inequalities in infant mortality is heartening.[11,236] One possible explanation for the improvement we saw in rural-urban inequalities in infant mortality is that, prior to the advent of the NHIS, a good proportion of rural dwellers had limited access to healthcare and were thus less likely to use both preventive and curative care.[1,67] With the implementation of the NHIS, this previously underserved population was able to afford and use essential healthcare services, and this may underlie the gains in infant mortality we observed for rural dwellers.[25,47] For urban dwellers, who had better access to healthcare even under the "cash-and-carry" regime, the improvements in healthcare access and hence health outcomes were much less marked.

It is also worth mentioning the government's other efforts to expand healthcare coverage such as the Free Maternal Healthcare policy,[177] which was introduced in 2008 to complement the NHIS. This policy removed the requirements for registration, the mandatory processing time for issuing insurance cards, and the need to pay premiums for all healthcare provided for pregnancy and delivery-related conditions. This meant a pregnant woman, not previously registered under the NHIS, could walk into a hospital and be seen immediately without regard for whether she was enrolled in the NHIS or not. This considerably improved access to care, especially for rural dwellers, by removing financial and administrative obstacles.

Another government intervention aimed at improving healthcare access has been the Community-based Health Planning Services (CHPS)[281] program. This program embeds

community health workers and nurses in communities without easy access to healthcare facilities. These serve as frontline workers to provide preventive health services, administer basic medical care including providing prenatal care services, and applying the Integrated Management of Childhood Illness (IMCI)[282] approach to managing common childhood conditions. They also act as first responders identifying and referring complicated cases for care at higher centers. While not directly linked to the NHIS, the presence of these paramedical personnel in rural communities has helped improve the utilization of care by improving the geographical availability of care in these rural areas and may have likely contributed helped to narrow the rural-urban gap in utilization and thus consequent outcomes.

We must also credit government's efforts in expanding access to life-saving public health interventions such as vaccination. Vaccination coverage in Ghana improved considerably over the study period. Ghana has added additional vaccines to its regime including the pneumococcal and rotavirus vaccines which combat some of the most important early childhood killers: sepsis and diarrhea. In addition to all vaccination being free in Ghana, frequent outreach programs are organized to ensure that people in hard-to-reach places do not miss out on vaccines because of the inability to reach a health facility.[180,229,283] In addition to improving overall child survival, the efforts made to reach every child in the country with these interventions has likely contributed to narrowing the urban rural-gap in survival.

The independent contributions of these programs to reducing inequalities in early childhood mortality outcomes cannot be easily divorced from that of the NHIS. However, the fact that the reduction in rural-urban inequalities, which we found in this paper occurred over a relatively

short period in the immediate aftermath of the implementation of the policy suggests that the NHIS is mainly responsible.

Other broad socio-economic and cultural changes may have contributed to the gains in equity seen since the NHIS came on-stream. Over the past 20 years, literacy in Ghana has improved considerably while poverty has greatly reduced.[284] These improvements in education, income and wealth are known to independently affect health outcomes via pathways outside the healthcare system—including improved nutrition, sanitation and the reduction of harmful health behaviors.[79] These socio-economic trends may differ in their impact on rural and urban dwellers and thus affect rural-urban inequalities in health outcomes. However, the trends in question change at a relatively slow pace, and are not likely to be responsible for the sudden dip in inequalities we observed.[141,251,252]

5.6.1 Limitations

This study suffers a few limitations, which must be considered in interpreting its findings. Most of these emanate from the fact that the data used in this study were not collected with this study's design and objectives in mind.

As with all studies conducted using survey data, our results are prone to errors emanating from misclassification of responses. In this case, a likely source of these issues is variations in the wording of questionnaires and coding of answers across different surveys.

The first potential source of data error is sampling. We combined data from multiple surveys conducted at different times and with different sampling methodologies. We accounted for the variation in sampling strategies in part by applying denormalized sampling weights in our

analyses, however it must be kept in mind that the sampling weights were provided for mothers and not births, which were our unit of analysis. One potential source of error in this regard is that we could be missing births to mother who died and thus could not be interview. This is potentially important as maternal mortality is known to be higher for rural as compared to urban mothers. However, we could reasonably expect that trends in maternal mortality would remain relatively constant or change relatively slowly over time and thus, could not be responsible for a sudden drop in inequality as we found.

The responses provided in the data are themselves potential sources of error. In the first place, we assumed that the mother's current residence (i.e. whether rural or urban) indicates the place of birth of the child, and that all children are raised in the same type of location as they were born in for the first year of life. This is not necessarily the case as it does not account for migration history, and this could lead to misclassification of rural-urban residence. With that said, we expect that the narrow window of follow-up we used in this study should reduce the magnitude of such misclassification. Further, since the levels of rural-urban migration are much higher than urban-rural migration, we would expect this misclassification to attenuate the observed disparities between rural and urban dwellers. We were unable to disaggregate the contribution of migration to our findings.

Also, mothers were asked to provide information on dates of birth and death for all children they have had. Considering that a considerable proportion of mothers sampled had no education, it is possible these responses are not completely reliable. In surveys like the DHS, the phenomenon of "heaping" where respondents are more likely to provide age or date information corresponding to nicely rounded figures (such as multiples of 10, 5 or 2), thus resulting in a discontinuous

distribution of ages/dates, has been well documented.[256,257] We did not account for this in our analyses. However, it would be expected that any such heaping would affect both urban and rural mother equally and so the impact of this would potentially cancel out.

The use of time series analyses in general, and interrupted time series analyses in particular assumes that observed past trends are predictors of future trends. This is not always the case as changes in unmeasured drivers of outcome trends may occur. For example, we did not account for urbanization in our study as we could not measure it, however, it could be a source of variation in the outcome as places previously classified as rural take on the socio-economic and demographic characteristics of urban areas.

Another potential source of error is that the ITS model we pre-specified could have been mis-specified. While we remain reasonably confident of the inferences we've made from our results for the study period, we advise caution in extrapolating these findings to future time periods or other contexts.

5.7 Conclusion

In this study, we found evidence that despite its many challenges, the introduction of the NHIS policy may have helped to reduce the disparities in infant mortality. As one of the pioneering social insurance schemes in sub-Saharan Africa, it is encouraging to know that the policy is on course to achieve at least some of its equity goals. It would also be worth investigating the underlying mechanisms driving these gains so lessons can be passed on to benefit future attempts at implementing similar programs

6 THE ROLE OF HEALTHCARE UTILIZATION IN EXPLAINING RURAL-URBAN DIFFERENCES IN NEONATAL AND INFANT MORTALITY

6.1 Preface

Rural urban disparities in early childhood mortality have been attributed to household and community factors. In particular, disparities in socioeconomic position and access to healthcare services have been blamed for the rural-urban gap.[266] In this chapter, I explore the role of skilled attendance at birth in driving rural-urban disparities in early childhood outcomes. The findings from this study should shed light on the mechanisms that underlie the contribution of skilled attendance to disparities in neonatal and infant mortality. Understanding these mechanisms should help explain how UHC policies like the NHIS, which are essentially aimed at improving healthcare access, (and consequently, utilization) would influence neonatal and infant mortality, and especially on rural-urban disparities in these outcomes.

Infant mortality has been decreasing globally over the past couple of decades with the exception of some parts of sub-Saharan Africa.[73,285] In Ghana, the infant mortality rate decreased by an average of about 1.2% per year between 1988 and 2008 from about 72 to 58 per 1,000 live births. Neonatal mortality also decreased by about 0.6% per annum over the period falling from 48 to 33 per 1000 live births. Neonatal mortality, however still accounted for about half of all under-5 deaths in 2014.[227] It appears however, that these benefits have not accrued evenly to all. Rural dwellers have consistently suffered worse outcomes compared to their urban counterparts.

Data from the past 10 years shows that rural children are more likely to die before their first birthday and about 25% more likely to die before their fifth.[164,166] Evidence from the Ghana Demographic and Health Survey of 2014 showed that only 83% of pregnant rural women

attended the recommended minimum of 4 antenatal visits compared to 97% of their urban counterparts. Similarly, while skilled birth attendants delivered 90% of urban newborns, only 60% of rural babies enjoyed that privilege. These disparities have persisted even in the face of policy interventions to close gaps in access to, and affordability of health services. Despite its importance, this problem is yet to be fully understood.

Factors that contribute to healthcare service utilization fall into two classes. There are supply-side factors such as the availability of services, and factors such as affordability, which influence demand. These factors differ in their distribution between urban and rural areas, and hence contribute to rural-urban disparities in healthcare services utilization, as well as in the health outcomes which are influenced by healthcare services utilization.

In this instance, we consider how skilled attendance at birth, a measure of healthcare utilization, contributes to rural-urban disparities in early childhood mortality.

6.2 Abstract

Background: As Universal Healthcare Coverage reforms are promoted by the WHO as a necessary part of achieving the health-related Sustainable Development Goals, there is a need to understand how the improvements in healthcare utilization that they promote translate into equity in health outcomes. We examine the mechanisms underlying the role of healthcare utilization as a driver of rural-urban disparities in neonatal and infant mortality in Ghana from 1993 to 2013.

Data and methods: We constructed neonatal and infant mortality samples using birth history records from the Ghana Demographic and Health Surveys from 1993 to 2014. We applied the VanderWeele 3-way decomposition approach for estimating direct, indirect and interaction/mediated pathways contributing to the observed effect of an exposure in the presence of a third variable acting as a mediator/interactor and adapted it for evaluating disparities. We estimated the components of the decomposition using a targeted maximum likelihood estimation approach

Findings: After accounting for socio-economic and cultural factors, we found a total rural-urban disparity in infant mortality of 3.6 [-9.8, 14.6] deaths per 1000 live births to the disadvantage of rural dwellers. This was made up of a pure indirect component of 4.2 [0.9, 8.3] per 1000 live births, a mediated interaction component of -4.1 [-8.6, -0.4] deaths per 1000 live births and a pure direct effect of 3.6 [-9.8, 14.6] per 1000 live births. For neonatal mortality, the corresponding values were a total rural-urban of 5.5 [-3.3, 14.8] deaths per 1000 live births a pure direct effect of 6.1 [-2.6, 15.8], a pure indirect effect of 2.0 [-0.3, 4.4] and a mediated interaction of -2.6 [-5.3, -0.1] deaths per 1000 live births.

Conclusions: We conclude that rural-urban inequalities in infant mortality may be influenced by both the availability and quality of healthcare services.

6.3 Introduction

In this paper, we explored the role of skilled attendance at birth as a driver of rural-urban disparities in early childhood mortality in Ghana. In the face of a general decline in neonatal and infant mortality worldwide over the past three decades, progress in improving these outcomes in sub-Saharan African countries appears to have stagnated.[73,286] While arguably making better progress than most, Ghana, like other countries in the sub-region has struggled to maintain the momentum of positive change, especially in the past decade.[227] Of particular interest is the persistence of an apparent rural disadvantage in these outcomes, which poses a considerable challenge to policy-makers tackling maternal and child health issues across the sub-region.[287–289]

Understanding the underlying mechanisms driving the rural-urban inequalities is critical to developing effective policies to mitigate them. While rural-urban disparities in mortality outcomes have been attributed to differences in the distribution of household- and community-level factors such as wealth and access to healthcare services,[266] individual-level factors such as health seeking behavior also play important roles.

Healthcare utilization is of interest in this regard because 1) it is often the target of government policies meant to improve health outcomes, and 2) it is a common metric by which the effectiveness of such policies is evaluated. As our specific measure of healthcare utilization in this study, we used skilled attendance at birth. We defined skilled attendance at birth as a composite of having a skilled attendant at birth and delivering in an appropriate health facility, Skilled attendance at birth matters for the evaluation of rural-urban disparities in early childhood mortality because intrapartum events (such as birth injuries, neonatal infection, prolonged

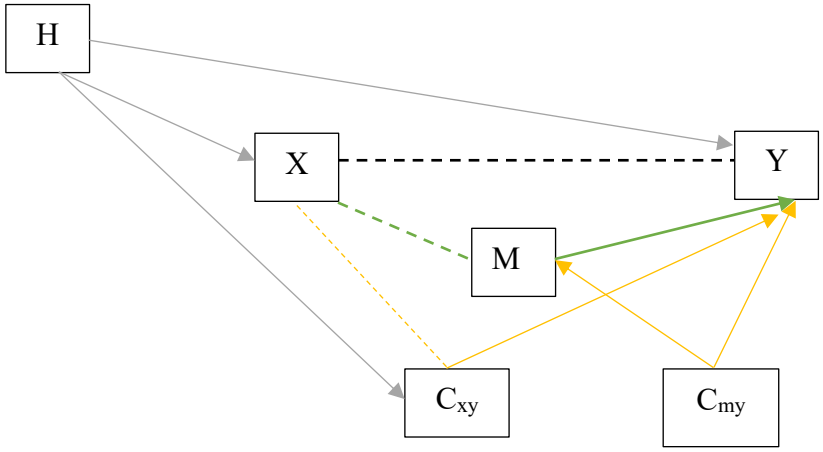
obstructed labor) are important determinants of neonatal and infant morbidity and mortality.[290,291] In addition, improving skilled attendance at birth has been a key aim of the Government of Ghana's flagship social health insurance program, the National Health Insurance Scheme (NHIS).[1,177]

The relationship between healthcare utilization and health outcomes is complex. While healthcare utilization undoubtedly plays a role in determining health outcomes, improvements in healthcare utilization do not necessarily lead to commensurate improvements in health outcomes.[72,292] The health of an individual depends on many other factors, which act via pathways independent of healthcare utilization to influence health outcomes.[72,73,291] For example, whiles a baby's survival is dependent on the care the mother received during pregnancy and labor, if the baby doesn't receive adequate nutrition after birth, his/her chances of survival could still be compromised. Even provided that increased healthcare utilization translates into improved health outcomes, this wouldn't necessarily result in a reduction in disparities in outcomes, as health gains may differ for different sub-populations. It is possible to achieve an overall improvement in health outcomes even if all the improvement is concentrated in one sub-population and inequalities in the outcome are worsened as a result.[24]

Thus, even if interventions on healthcare utilization are successful in improving health outcomes, there is still the need to examine the question of whether they have improved equity in health outcomes, and beyond that, to understand how they have achieved that (if at all). This knowledge would be invaluable in planning and implementing future UHC programs so they can better

achieve their equity goals. In this paper, we contribute to the state of knowledge on the role of

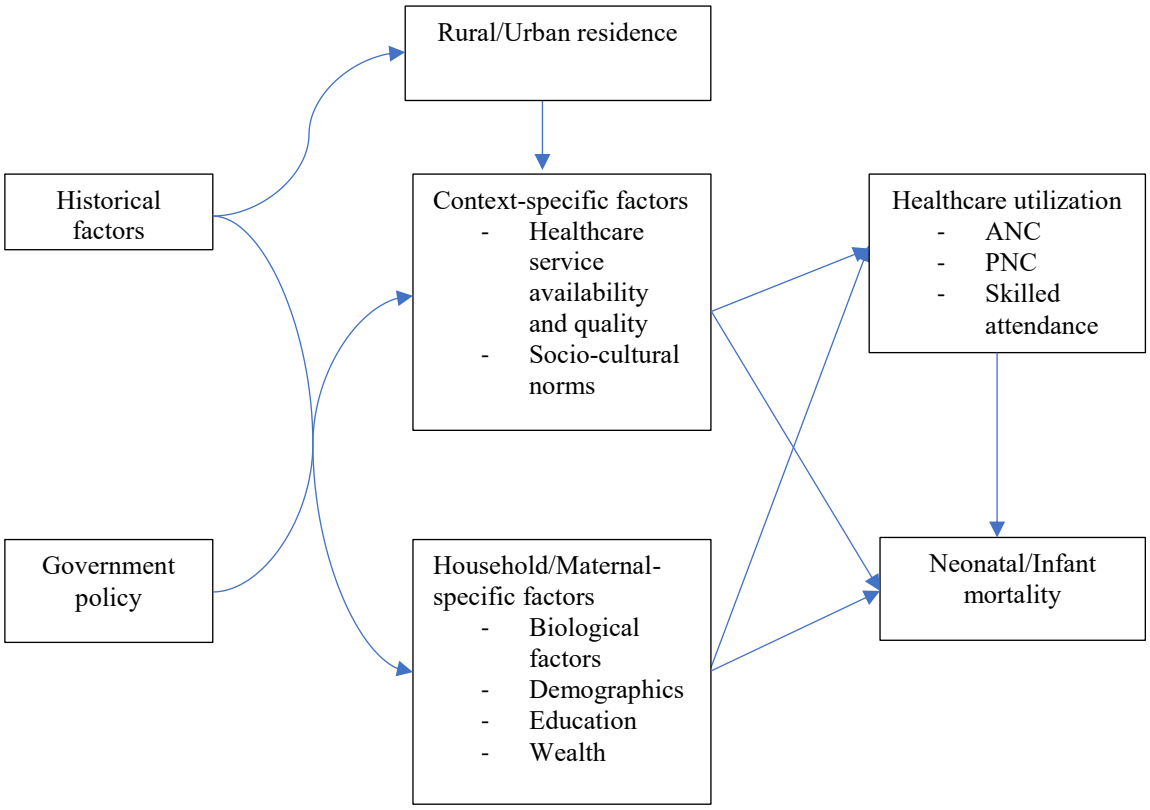
Figure 6-1: Relationships between historical factors, rural/urban residence, healthcare utilization and outcomes.



Note:
X = rural/urban residence (exposure)
M = healthcare utilization (M)
Y = outcomes (early childhood mortality)
Cxy = causes of outcome which are distributed differently by rural/urban residence (X)
Cmy = common causes of healthcare utilization (M) and outcome

The dashed lines represent differences in distribution of factors (Y, Cxy, M) by rural/urban residence (X). These are non-directional as rural/urban residence is not readily intervened on and is not considered a cause in that sense. These dashed arrows define rural-urban inequalities in these factors

Figure 6-2: Conceptual framework showing interrelationship between various contributors to neonatal and infant mortality



ANC=Antenatal care; PNC=Postnatal care

The figure shows the relationships between distal factors (historical, government policy), intermediates (contextual and household factors) and proximate determinants (such as healthcare utilization), and early childhood mortality. While these relationships are generally complex and the flow of causality is often bi-directional, the arrows here show the general direction of the net causal influence between these factors. The flow of the arrows also loosely reflects temporality.

healthcare services utilization in driving rural-urban disparities in early childhood mortality outcomes. We do this by assessing the contributions of differences in the distribution and effect of skilled attendance between rural and urban areas, to the rural-urban disparity in neonatal and infant mortality using the VanderWeele 3-way decomposition approach.

6.4 Methods[4]

6.4.1 Causal Mediation and interaction

The concepts of interaction and mediation are often used to explain the mechanisms by which exposures exert effects on outcomes.[222,293] In the context of a causal exposure, an interaction effect represents an excess (or deficit) of outcomes due to the simultaneous effect of two factors (exposure and third factor), compared to the summation of their independent effects. A mediation effect results from the third factor lying on the pathway of effect from exposure to outcome. In a typical mediation analysis, we separate the total effect of an exposure into direct effects which persist in the absence of the mediator and indirect effects whose pathway of action includes the mediator. Assessing interaction effects on the other hand involves determining how the effect of exposure on an outcome varies with changing levels of the interacting variable.[223]

6.4.2 The VanderWeele 3-way decomposition

While often dealt with as separate phenomena, interaction and mediation often occur together between the same three variables (for expositions purposes, let's assume: exposure, X, outcome Y, and mediating/interacting variable, M). VanderWeele (2013)[88] proposed a framework for examining interaction and mediation effects jointly for any three such variables. In this framework the total effect of X on an Y in the presence of M may be thought of as made up of the independent effect of X on Y (the pure direct effect), the effect of X on Y carried through the

[4] For our subsequent discussions, we will use the following notation.
Y_m = value of Y for M = m
Y_{xm} = value of Y for X = x and M = m
Y_x = value of Y for X = x
M_x = value of M for X = x

independent effect of M on Y (the pure indirect effect), and an additional component due to the joint effects of X and M on Y (the mediated interaction effects).

Of note, the components of the VanderWeele decomposition represent natural effects rather than controlled effects. This means they are derived from setting the values of the mediator to the value they would have under a certain reference level of the exposure. In other words, the value of the mediator for any individual would vary depending on the exposure-mediator relationship for that individual. This is in contrast to the estimation of controlled direct effects which involves setting the mediator to a single value for all members of the population.

6.4.2.1 Estimation of effects in the VanderWeele 3-way decomposition approach

The 3-way decomposition method VanderWeele proposed enables the total effect of the exposure on the outcome to be broken down into three components: one due to mediation alone, and the last due to mediation and interaction and the last due to neither mediation nor interaction.[215,223] These components are referred to as the pure direct effect, (independent effect of exposure), the pure indirect effect (effect carried uniquely through the mediator), and the mediated interaction, (additional effect from joint action of exposure and third variable acting through the mediated pathway).

Mathematically, this approach decomposes the total effect thus:

$$Y_1 - Y_0 = \left(Y_{1M_0} - Y_{0M_0}\right) + \left(Y_{0M_1} + Y_{0M_0}\right) + (Y_{11} - Y_{10} - Y_{01} + Y_{00})(M_1 - M_0)$$

The first component $\left(Y_{1M_0} - Y_{0M_0}\right)$, represents the pure direct effect, the second $\left(Y_{0M_1} + Y_{0M_0}\right)$, the pure indirect effect, and the third $(Y_{11} - Y_{10} - Y_{01} + Y_{00})(M_1 - M_0)$, the mediated

interaction effect. These components of effect in this case cannot be identified for individuals in empirical data. However, population-average estimates for these components can be obtained.

We adapt the approach used by VanderWeele to explain the role of skilled attendance in driving rural-urban differences in outcomes. For our binary exposure and mediator, the following equations apply:

Equation: 17: $TE = PDE + INT_{med} + PIE$

Equation: 18: $PDE = \sum_m \{E(Y|X = 1, m, c) - E(Y|X = 0, m, c)\} P(m|X = 0, c)$

Equation: 19: $PIE = \sum_m E(Y|X = 0, m, c)\{P(m|X = 1, c) - P(m|X = 0, c)\}$

Equation: 20: $Int_{med} = \{E(Y|X = 1, M = 1, c) - E(Y|X = 1, M = 0, c) - E(Y|X =, M = 1, c) + E(Y|X = 0, M = 0, c)\}\{E(M|X = 1, c) - E(M|X = 0, c)$

Where:

TE = Total effect of exposure

PDE = Pure direct effect

Int_{med} = Mediated interaction component

PIE = Pure indirect component

We also estimated the equivalent component quantities on the ratio scale:

Equation: 21: $RR^{TE} = \frac{E(Y_1|c)}{E(Y_0|c)}$

Equation: 22: $RR^{DE} = \frac{E(Y_{1M_0}|c)}{E(Y_{0M_0}|c)}$

Equation: 23: $RR^{IE} = \frac{E(Y_{0M_1}|c)}{E(Y_{0M_0}|c)}$

Equation: 24: $RERI_{med} = \{\frac{E(Y_{1M_1}|c)}{E(Y_{0M_0}|c)} - \frac{E(Y_{1M_0}|c)}{E(Y_{0M_0}|c)} - \frac{E(Y_{0M_1}|c)}{E(Y_{0M_0}|c)} + 1\}$

Where:

RR^{TE} = Total effect of exposure on the ratio scale

RR^{DE} = Pure direct effect on the ratio scale

RR^{IE} = Pure indirect effect on the ratio scale

$RERI_{med}$ = Mediated relative excess risk due to interaction

These quantities on the ratio scale are related by

Equation: 25: $(RR^{TE} - 1) = (RR^{DE} - 1) + (RR^{IE} - 1) + RERI_{med}$

In other words, the excess relative for the total effect is the sum of the excess relative risks for the pure direct and pure indirect effects, and the mediated relative excess risk due to interaction.

6.4.2.2 Identification of effects in the VanderWeele 3-way decomposition approach

As with any typical causal mediation analysis, the interpretation of the components of the VanderWeele decomposition as causal quantities would require assumptions of consistency (i.e. that Y_x and M_x are equal to the observed outcome and mediator levels respectively, when X is set to x) and composition (i.e. that the counterfactualY_{xM_x}, the value of Y when x is set to x and M is set to the counterfactual value of M when X is set to x, is equal toY_x). In addition, the interpretation of the components of the VanderWeele 3-way decomposition as population-average causal effects would require the following assumptions, which are also commonly applied in elucidating causal mediation effects:

1) No exposure-outcome confounding conditional on measured covariates ($Y_{xm} \perp X|C$)
2) No mediator-outcome confounding conditional on exposure and measured covariates ($Y_{xm} \perp M|\{C, X\}$)
3) No exposure-mediator confounding conditional on measured covariates ($M_x \perp X|C$)
4) Mediator-outcome confounders should be independent of exposure

6.4.3 Mediation analysis for disparities

As mediation conceptually concerns pathways of exposure-effect the causal effect of exposure must itself be identified for any mediation effect to have a meaningful interpretation. Under the potential outcomes framework of causal inference, a causal effect is defined as a contrast between the outcome when exposure is set to one level versus the outcome when set to another level. This presents a potential problem when applied to disparities. The exposures typically encountered in disparities research are not easily intervened on and thus they do not neatly fit this definition of causation. Consequently, the concepts of mediation and interaction also have to be approached differently.

An archetypical example of this is race. One approach that has been suggested as a way of defining racial disparities as causal effects is to consider the effect of race as the sum total of the effects of the different elements that together define race—physical phenotype, parental phenotype, cultural and social context and experience etc. One issue with this approach is that, the component effects would also need to be defined in terms of potential outcomes associated intervening on the corresponding variables. These components are potentially numerous, and not always easy to intervene on.

One alternative approach is to define causal effects indirectly in terms of interventions on a mediator. In this approach, the changes in the level of disparity when the distribution of the mediator across levels of the "exposure" is changed are interpreted as components of the causal effect of the "exposure." VanderWeele and Robinson (2013) proposed that given adequate confounder control, the direct effect of exposure (direct component of the disparity) represents the disparity that would remain if the distribution of the mediator in the reference population was

made equal to the distribution of the mediator in the exposure population. In this paradigm, the causal indirect effect could be interpreted as the change in the outcome for the reference population if the mediator in this population was changed from the reference level. Naimi et al (2016)[213] applied this approach to evaluate the direct component of the racial disparity in health outcomes, which they called the counterfactual disparity measure (CDM).

Defining causal effects of disparities in terms of interventions on mediators raises a number of interesting issues. One important concern has to do with the question of confounding and how it is handled. Since this paradigm, accepts that exposure cannot be intervened on, the concepts of exposure-outcome and exposure-mediator confounding are not clearly defined. Conceptually, what would have constituted backdoor pathways could be thought of as carrying important components of the disparity. Since under this paradigm, there is no question of intervening on the exposure variable, it's hard to ascribe directionality to pathways of effect originating or terminating on the exposure. This also has implications for the assumptions underlying the identification of causal mediation effects as we discuss later. Researchers may still, however want to standardize their estimates by important causes of the outcome which may be distributed differentially across levels of exposure. This may be done to allow for important ethical considerations to be made in interpreting the estimates and not necessarily for reasons of causal validity.

6.4.4 Approach used in this paper

In this paper, we explored rural-urban disparities in early childhood mortality outcomes. We considered rural-urban residence as not amenable to practical policy intervention. While individuals do move from rural to urban areas and, to a lesser extent, from urban to rural areas,

relocating any substantial portion of the rural population to urban areas or vice versa, is not feasible as a policy intervention. For the purposes of this paper, the differences in the distribution of the outcomes between rural and urban-born children correspond to our exposure effect. This "effect" may result from differences in the distribution, or magnitude of effect of causes of the outcome, between the two population strata. Those causes of the outcome, whose differential distribution and/or effect drive rural-urban disparities in our outcomes, are analogous, for our purposes, to causal mediators (and/or interaction variables). Their differential distribution may be compared to a causal mediation effect while their differential effects correspond to interaction effects.

We applied the VanderWeele decomposition approach to examine the mediation of rural-urban disparities in neonatal and infant mortality by the use of skilled attendance. The intuition behind our use of this decomposition approach in this paper is as follows: Rural-urban differences in neonatal and infant mortality may arise by either of two pathways, from which we derive parallels of the components of the VanderWeele decomposition.

The pure direct component is equivalent to that portion of the disparity which would remain if all woman were assigned the level of skilled attendance they would have had if they delivered in a rural area. It results from the action of factors which act independent of skilled attendance to cause neonatal or infant mortality.

The additive interaction effect of skilled attendance with rural-urban residence corresponds to the excess mortality observed among rural dwellers who do not use skilled attendance are compared to the combined mortality among rural dwellers who use skilled attendance and urban dwellers who don't use skilled attendance. The mediated interaction component of the disparity

decomposition represents this excess mortality weighted by the difference in the prevalence of skilled attendance between urban and rural areas.

The final component, the pure indirect component, corresponds to the portion of the total disparity that results from differences in the rates of skilled attendance between urban and rural areas, that are in turn due to factors unique to being and urban or rural dweller. This component represents the portion of the total disparity that is carried uniquely via skilled attendance.

Another way to think of these components is in terms of the policy approaches they correspond to. Considered this way, the pure direct component reflects that portion of the rural-urban disparity that is not amenable to interventions that aim to solely improve skilled attendance rates. It represents the potential improvement in rural-urban disparities that would result from intervening on other factors that influence neonatal and infant mortality outcomes, such as maternal education, nutrition and environmental factors.

The mediated interaction component reflects the potential additional impact on rural-urban disparities, of intervening to enhance the quality of skilled attendance, in addition to improving its availability in rural areas, without influencing the non-health-system factors that contribute to rural-urban disparities in outcomes. Such improvement in the quality of skilled attendance services could result from making potentially life-saving interventions such as caesarian sections and blood transfusion readily available in rural areas.

The pure indirect component estimates the improvement that would be seen in rural-urban disparities if we intervened on the factors that drive rural-urban differences in skilled attendance rates. This could include educational interventions, improving socio-cultural norms which

prevent rural women from fully utilizing skilled attendance services, improving geographic access to health facilities etc.

In adapting the VanderWeele decomposition approach to evaluating disparities, we reiterate that our exposure (rural/urban residence) is not amenable to intervention in any practical sense.[297] Consequently, we relax assumption 1.[213] We also relax assumptions 3 and 4 for the same reason. In doing so, we affirm that the causal pathways, which carry the "effects" of exposure in this context, must be conceptualized differently. What would have been ordinarily considered backdoor paths carry part of the disparity and must be considered in estimating the total disparity? In other words, we must necessarily include the contribution of some factors which are common causes of exposure and outcome—factors which would have been treated as confounding variables to be adjusted for in traditional causal and mediation analyses. With that said, we note that researchers may still choose to standardize their estimates to the distribution of one or more covariates to apply a-priori ethical or substantive assumptions rather than to remove bias (as we did in this study).[270] In this study, we adjusted for factors, which contribute to the rural-urban disparity, but which are not amenable to direct policy intervention.

With that said, we note that there is a requirement for the causal pathway from the mediator to outcome to be unconfounded. In pursuance of this, we adjusted for factors which influence both skilled attendance at birth and our outcomes. In this regard, we adjusted for socio-economic factors such as maternal education, and household wealth as well as socio-cultural factors such as maternal age at first birth, marital status and religion as discussed above. In considering how to handle any possible confounding of this pathway, we also note that we have reason to believe

there would be and interaction between skilled attendance at birth and rural/urban residence. We explore this in our analysis.

One way to think of these relationships is that disparities in outcomes arise from differences in the distribution of causes of the outcome between the population strata of interest. The direct pathway of effect from exposure to outcome captures the effect of unmeasured factors which differ in distribution between the population strata, while the indirect paths (including mediated and interaction pathways) correspond to the portion of the total effect attributable to measured factors which again differ in distribution between the population strata.[297]

6.4.5 Data

We used birth history data from the Demographic and Health Surveys (DHS) for Ghana conducted in the years1993, 1998, 2003, 2008, 2014—specifically, versions of the DHS datasets with harmonized variables provided by the International Public Use Microdata Series (IPUMS) program.[116,186,187] The DHS are a series of multi-stage-sampled, nationally representative surveys which use standardized measures and data gathering methodologies, thus allowing valid comparisons to be made across surveys. The target populations for these surveys are all women of child-bearing age (15 years to 49 years) and children up to five years old.

In these surveys, census lists were used as the primary sampling frame from which enumeration areas were selected using a probability proportional to size method. All women in selected households were interviewed. They were asked questions on all births they had ever had up to a maximum of 20 children.[186] In the Ghanaian DHS surveys included in this study, the women were asked for information concerning perinatal and intrapartum care received for any pregnancy they had had in the five years preceding their interview.

For our analysis of neonatal mortality, we used a sample of all births which occurred between a month and five years before mothers were interviewed. We followed the children up from birth to 28 days of age. We gathered a similar sample of children born between one and five years before the mother's interview date with follow-up from birth to 12 months, for our analysis of infant mortality. We in effect excluded any child who was alive when his/her mother was interviewed and less than a month old from our neonatal mortality analysis. Similarly, living children less than a year old at time of interview were excluded from our infant mortality analysis. These children were excluded because their eventual outcome statuses were unknown at the time data was being gathered.

We weighted all mothers using denormalized DHS weights.[116] We estimated these weights as

Equation: 26: $$W_{it} = \frac{n_t}{P_t} * w_i$$

Where

w_i is the individual sample weight provided in the DHS dataset for each woman *i*,
n_t is the number of women aged 15 – 45 years interviewed in Ghana in survey year t
P_t is the population of females aged 15 – 45 years in Ghana in survey year t

We used United Nations estimates for the Ghanaian population.[294] in calculating these weights.

6.4.6 Measures

Our outcomes of interest (henceforth designated Y) were neonatal mortality defined as the death of a child within 28 days of birth, and infant mortality defined as the death of a child within 12 months of birth. Our independent variable was a binary indicator of rural-urban residence (henceforth designated X), which we defined as being born to a mother who was living in a rural

or urban area, as designated in the most recent Ghana Population and Housing Census,[269] at the time of being surveyed. This definition is essentially the same as that used in the DHS.[116]

We explored the role of skilled attendance at birth (used as a proxy measure of health service utilization, henceforth designated M) as a mediator of the association between rural-urban residence and neonatal/infant mortality. Skilled attendance in this case was defined as delivery in an appropriate health facility, attended by a trained health professional. Appropriate health facility as used here includes all health facilities, government or private which are equipped to provide at least basic emergency obstetric care. Trained health professionals include doctors, nurses and midwives, but exclude trained traditional birth attendants.

As we expected rural dwellers and women who do not use skilled attendance to have higher mortality levels, we coded urban dwellers and women who use skilled attendance as our reference level (0). We coded rural dwellers and women who do not use skilled attendance as 1.

We considered household wealth (represented in our models as quintiles of an asset index derived from a principal components analysis of household assets[243]), maternal education (categorical variable: none, primary, secondary, post-secondary), religion (categorical: Christian, Muslim, Traditional, none), age at first birth (categorical), and marital status (binary: not in a union, in a union) as possible confounders of the effect of our mediator (skilled attendance) on the outcomes (henceforth designated C_{MY}). Religion and age at first birth reflect socio-cultural norms which may influence health seeking behavior as well as independently affect the outcomes.[81,252,295] For example, traditional norms promoting exclusive breastfeeding may improve infant survival.[296] We included indicator variables for child's birth year to account for secular trends in our outcomes.

In addition to examining and decomposing the natural mediation effects of skilled attendance on rural-urban disparities in our outcomes, we estimated the controlled direct effect of assigning skilled delivery to be a particular level for everyone in the population, on the rural-urban disparities in our outcomes. These measures, which we designated as counterfactual disparity measures (CDM) in line with Naimi et al. (2016) estimate the hypothetical effects of intervening on the mediator (skilled delivery). The counterfactual disparity measure for setting skilled attendance to 0 (CDM (M=0), represents the change in the rural-urban disparity that would result from assigning all women, both rural and urban, to have skilled attendance at birth. Its corollary, CDM (M=1) represents the counterfactual scenario where no woman receives skilled attendance at birth (an implausible policy intervention).

Equation: 27: $CDM_{[M=m]} = CDM = E[Y^{M=m}|X=1] - E[Y^{M=m}|X=0]$ [213]

6.4.7 Statistical analysis: Targeted Maximum Likelihood Estimation

In this paper, we estimated the components of the VanderWeele 3-way decomposition using a Targeted Maximum Likelihood Estimation (TMLE) approach. TMLE is a semiparametric, efficient, substitution estimator, which solves the efficient score equation. The TMLE provides consistent, doubly robust estimates of the components of our decomposition. It achieves this by modeling both the outcome and the exposure mechanisms.[298]

Our method for deriving the components of the decomposition was adapted from Naimi et al (2016).[213] In that paper, the authors demonstrated the estimation CDM using several methods including a TMLE. In this paper, we extended their TMLE approach to estimate the CDM as well as the components of the VanderWeele 3-way decomposition. The details of our method are provided below.

We define the following terms as used in the subsequent equations below:

- $Q_2^{x,m}$, $Q_1^{x,m}$ = initial outcome predictions under X = x and M = m
- $Q_2^{*x,m}$, $Q_1^{*x,m}$ = updated outcome predictions under X = x and M = m
- $\varepsilon_1, \varepsilon_2$= first and second fluctuation parameters respectively
- C_{XY} and C_{MY} represent exposure-outcome and exposure-mediator confounders respectively
- $\frac{I(X=x,M=m)}{(1-\hat{E}(M|X=x,C_{MY},C_{XY})(\hat{E}(X|C_{XY})}$, $\frac{I(X=x)}{(\hat{E}(X|C_{XY})}$ = first and second "clever covariates"
- $I(.)$= 1 if (.) is true; 0 otherwise
- $Invlogit(.) = exp(.)/(1 + exp(.))$

To estimate the TMLE, we estimate the following equations:

Equation: 28: $E(Y|X, M, C_{MY}, C_{XY}) = invlogit(\gamma_0 + \gamma_1 X + \gamma_2 M + \gamma_2 XM + \gamma_3' C_{XY} + \gamma_4' C_{MY})$

Equation: 29: $\widehat{\mathrm{E}}(\mathrm{M}|\mathrm{X} = \mathrm{x}, \mathrm{C_{MY}}, \mathrm{C_{XY}}) = \mathrm{invlogit}(\delta_0 + \delta_1 \mathrm{X} + \delta_2' \mathrm{C_{XY}} + \delta_3' \mathrm{C_{MY}})$

Equation: 30: $E(X|C_{XY}) = invlogit(\theta_0 + \beta_1 C_{XY})$

Equation: 31: $E(Y|X = x, M = m, C_{MY}, C_{XY}) = invlogit(\varepsilon_2 \frac{I(X=x,M=m)}{(1-\hat{E}(M|X=x,C_{MY},C_{XY})(\hat{E}(X|C_{XY})} + logit[Q_2^{x,m}])$

Equation: 32: $E(Q_2^{*x,m}|X, C_{XY}) = invlogit(\beta_0 + \beta_1 X + \beta_2 C_{XY})$

Equation: 33: $\mathrm{E}(\mathrm{Q_2^{x,m}}|\mathrm{X}, \mathrm{C_{XY}}) = \mathrm{invlogit}(\varepsilon_1 \frac{\mathrm{I(X=x)}}{(\hat{\mathrm{E}}(\mathrm{X}|\mathrm{C_{XY}})} + \mathrm{logit}[\mathrm{Q_1^{x,m}}])$

The first equation (Equation 28) is our outcome model relating the outcome, exposure, mediator and exposure-outcome and mediator-outcome confounders. The second equation (Equation 29) models the mediator as a function of exposure, exposure-outcome confounders and mediator-outcome confounders. The 3rd equation (Equation 30) models the exposure mechanism as a function of exposure-outcome confounders. Equations 4 to 6 are used to update initial predictions to obtain our targeted estimate.

We began our estimation of the TMLE by fitting a model for the outcome with exposure, mediator and mediator-outcome confounders as predictors (Equation 28). From this model we obtained initial predictions of the outcome setting X to 1 and M to 0 for all observations ($Q_2^{1,0}$). Next, we calculated the first clever covariate using inverse probability weights derived using outcome predictions from equations 2 and 3. We then estimated the first fluctuation parameter, ε_2 from a no-intercept model of the outcome against the first clever covariate with our initial predictions as an offset (Equation 31). (Note that, if our initial predictive model had been properly specified and provided us with unbiased predictions, this first fluctuation parameter would have been zero and we could have proceeded to calculate our components by generating $Q_2^{x,m}$ under all combinations of X and M). In this case, we proceeded to obtain updated predictions $Q_2^{*x\,0}$ from this model for all levels of exposure setting the mediator to 0. We then updated these predictions by regressing them against X and C_{XY} as in Equation 32. From this equation, we calculated updated outcome predictions for all individuals$Q_1^{*1,0}$. The mean value of $Q_1^{*1,0}$ averaged across all observations gave a targeted estimate of$E(Y_{m=0}|X=1)$. We repeated the above process, each time setting X and M to different values to obtain values for $E(Y_m|X=x)$ for all combinations of X and M. We input these values into the Equations 18 to 27 to obtain the components of our decomposition and CDMs. We obtained standard errors using a non-parametric bootstrap procedure.

We conducted all analyses in STATA 13.[247]. We provide STATA code for our analysis in the appendix.

6.5 Results

The characteristics of respondents in our neonatal and infant mortality samples are given in Table 6.1. In all, we had 14,684 births in our neonatal mortality sample (10,077 rural, 4,607 urban) and 12,364 births in the infant mortality sample (8,415 rural, 3,949 urban). In both samples, there was a distinctive gradient in maternal education favoring urban dwellers with about half of the rural mothers having no education, while almost half of the urban mothers had had at least secondary education. There was a similar gradient in household wealth with more than 70% of rural respondents being in the two poorest wealth quintiles while two-thirds of urban dwellers were in the two richest quintiles. The distributions of religion and the proportions of respondents married or in a union were quite similar between urban and rural-dwelling mothers across both samples. About 67% of respondents in urban areas used skilled attendance compared with only 39% in rural areas.

Table 6-1 Demographic characteristics of sample

	Neonatal Mortality Sample			Infant Mortality Sample		
	Urban N = 4,607	Rural N = 10,077	Total N = 14,684	Urban N = 3,949	Rural N = 8,415	Total N = 12,364
Maternal age at first birth						
< 19 yrs	313 (6.8)	794 (7.9)	1,107 (7.5)	276 (7.0)	671 (8.0)	947 (7.7)
20 – 24 yrs	1,011 (21.9)	2,424 (24.1)	3,435 (23.4)	884 (22.4)	2,071 (24.6)	2,955 (23.9)
25 – 29 yrs	1,317 (28.6)	2,529 (25.1)	3,846 (26.2)	1,095 (27.7)	2,084 (24.8)	3,179 (25.7)
30 – 34 yrs	1,050 (22.8)	1,954 (19.4)	3,004 (20.5)	914 (23.1)	1,616 (19.2)	2,530 (20.5)
>35 yrs	916 (19.9)	2,376 (23.6)	3,292 (22.4)	780 (19.8)	1,973 (23.4)	2,753 (22.3)
Maternal highest educational level						
No education	1,002 (21.7)	5,046 (50.1)	6,048 (41.2)	862 (21.8)	4,199 (49.9)	5,061 (40.9)
Primary	913 (19.8)	2,169 (21.5)	3,082 (21.0)	767 (19.4)	1,821 (21.6)	2,588 (20.9)
Secondary+	2,692 (58.4)	2,862 (28.4)	5,554 (37.8)	2,320 (58.7)	2,395 (28.5)	4,715 (38.1)
Religion						
Muslim	1,070 (23.2)	1,717 (17.0)	2,787 (19.0)	913 (23.1)	1,412 (16.8)	2,325 (18.8)
Christian	3,335 (72.4)	6,530 (64.8)	9,865 (67.2)	2,866 (72.6)	5,495 (65.3)	8,361 (67.6)
Traditional	202 (4.4)	1,830 (18.2)	2,032 (13.8)	170 (4.3)	1,508 (17.9)	1,678 (13.6)
None/Other						
Household asset index in quintiles						
Poorest	213 (4.6)	4,599 (45.6)	4,812 (32.8)	192 (4.9)	3,836 (45.6)	4,028 (32.6)
Poorer	332 (7.2)	2,908 (28.9)	3,240 (22.1)	287 (7.3)	2,430 (28.9)	2,717 (22.0)
Middle	903 (19.6)	1,696 (16.8)	2,599 (17.7)	785 (19.9)	1,419 (16.9)	2,204 (17.8)
Richer	1,538 (33.4)	691 (6.9)	2,229 (15.2)	1,302 (33.0)	575 (6.8)	1,877 (15.2)
Richest	1,621 (35.2)	183 (1.8)	1,804 (12.3)	1,383 (35.0)	155 (1.8)	1,538 (12.4)
Maternal current marital or union status						
Not in a union/single	614 (13.3)	976 (9.7)	1,590 (10.8)	557 (14.1)	840 (10.0)	1,397 (11.3)
In a union/Married	3,993 (86.7)	9,101 (90.3)	13,094 (89.2)	3,392 (85.9)	7,575 (90.0)	10,967 (88.7)
Skilled delivery						
No	3,808 (82.7)	3,867 (38.4)	7,675 (52.3)	3,276 (83.0)	3,310 (39.3)	6,586 (53.3)
Yes	799 (17.3)	6,210 (61.6)	7,009 (47.7)	673 (17.0)	5,105 (60.7)	5,778 (46.7)

Note: Data form IPUMS-DHS child datasets from Ghana; sample is of children born in Ghana between 1993 and 2013; All estimates are weighted with DHS denormalized weights

We explored the distribution of outcomes within strata of our exposure and mediator in our sample (Table 6.2). We found a neonatal mortality rate of about 36.2 [31.5, 41.0] per 1000 live births among rural dwellers and 33.7 [25.6, 41.8] per 1000 live births among urban dwellers.

Among urban dwellers, neonatal mortality rates were much lower among those who had skilled attendance compared to those who did not (26.9 [20.9, 32.9] per 1000 live births versus 42.6 [25.7, 59.6] per 1000 live births). Similarly, infant mortality rates were much lower among urban dwellers who had skilled attendance compared to those who did not. (40.6 [32.9, 48.2] vs. 75.0 [52.2, 97.8] per 1000 live births respectively). Interestingly, among rural dwellers, those who used skilled attendance had higher neonatal and infant mortality rates compared to those who didn't use skilled attendance. (40.0 [32.4, 47.7] vs. 31.2 [26.6, 35.9] neonatal deaths per 1000 live births, and 55.3 [45.8, 64.7] vs. 53.3 [46.7, 59.9] infant deaths) per 1000 live births respectively.

Table 6-2: Neonatal and infant mortality rates among mothers with and without skilled attendance

	Neonatal		Infant	
	Rural	Urban	Rural	Urban
Mortality levels				
Overall	36.2 [31.5, 41.0]	33.7 [25.6, 41.8]	54.4 [48.3, 60.6]	55.1 [44.5, 65.7]
Among those with skilled delivery	40.0 [32.4, 47.7]	26.9 [20.9, 32.9]	55.3 [45.8, 64.7]	40.6 [32.9, 48.2]
Among those without skilled delivery	31.2 [26.6, 35.9]	42.6 [25.7, 59.6]	53.3 [46.7, 59.9]	75.0 [52.2, 97.8]

Note: Data from IPUMS-DHS child datasets for Ghana. Sample is of children born between 1993 and 2013. Estimates derived from weighted logistic regression models with rural/urban residence, skilled delivery, interactions between skilled delivery and rural/urban residence. Confidence intervals derived from bootstrapping. Mortality rates are per 1000 live births

We present the results of our 3-way decomposition in Table 6.3 below. We found a total rural-urban disparity in neonatal mortality on the difference scale of 5.5 [-3.3, 14.8] deaths per 1000 live births (excess relative risk of the total disparity = 18.2 [-9.0, 58.3] percent). This decomposed into a PDE of 6.1 [-2.6, 15.8], a PIE of 2.0 [-0.3, 4.4] and an Int_{med} of -2.6 [-5.3, -0.1] deaths per 1000 live births. The CDM [M=0] was 11.7 [1.5, 21.4] deaths per 1000 live births.

For infant mortality, the total disparity was 3.6 [-9.8, 14.6] deaths per 1000 live births decomposing into a PDE of 3.5 [-10.3, 14.7], PIE of 4.2 [0.9, 8.3] and an Int_{med} of -4.1 [-8.6, -0.4] deaths per 1000 live births. The CDM [M=0] was 11.8 [-1.5, 24.2].

Table 6-3 Components of the VanderWeele 3-way decomposition of mediaton and interaction effects

	Neonatal mortality	Infant mortality
Total effect (per 1000 LB)	5.5 [-3.3, 14.8]	3.6 [-9.8, 14.6]
Pure direct effect (per 1000 LB)	6.1 [-2.6, 15.8]	3.5 [-10.3, 14.7]
Pure indirect effect (per 1000 LB)	2.0 [-0.3, 4.4]	4.2 [0.9, 8.3]
Mediated interaction (per 1000 LB)	-2.6 [-5.3, -0.1]	-4.1 [-8.6, -0.4]
Excess relative risk total effect (%)	18.2 [-9.0, 58.3]	6.9 [-16.4, 31.5]
Excess relative risk direct effect (%)	20.2 [-7.5, 62.3]	6.7 [-17.2, 32.2]
Excess relative risk indirect effect (%)	6.6 [-0.9, 13.6]	7.9 [1.8, 14.1]
Mediated relative excess risk due to interaction [RERI, %]	-8.7 [-16.6, -0.3]	-7.8 [-15.2, -0.9]
CDM [M = 0] (per 1000 LB)	11.7 [1.5, 21.4]	11.8 [-1.5, 24.2]
CDM [M = 1] (per 1000 LB)	-4.1 [-19.5, 10.7]	-12.4 [-31.8, 9.1]

Note: CDM=counterfactual disparity measure; estimates are from a TMLE which accounted for maternal age at first birth, maternal education, religion, household wealth and maternal marital status; models were also weighted with DHS denormalized weights. Confidence interval derived from bootstrapping

6.6 Discussion

We set out to explore the role of skilled attendance in driving rural-urban disparities in neonatal and infant mortality. We approached this question in two way. The first was descriptive, examining the contribution of skilled attendance to rural-urban disparities in the outcomes via various pathways—direct and indirect—and also via interaction with rural/urban residence. The second explored the potential impact of intervening on skilled attendance.

We began by exploring our data. We found that urban dwellers were much more likely to have skilled attendance at delivery compared to rural dwellers. Interestingly, while we found both infant and neonatal mortality to be related to skilled attendance rates, the direction of the crude association among rural dwellers was opposite to that among urban dwellers. Skilled attendance was associated with improved mortality outcomes for urban dwellers but appeared to be harmful for rural dwellers.

In interpreting the findings of our VanderWeele 3-way decomposition, we must note that we adjusted for variables, which were associated with early childhood mortality and distributed unevenly between urban and rural areas,[68,266,299] and that by so doing, we removed a considerable part of the rural-urban disparity that is not carried via healthcare services utilization. We effectively attenuated the direct pathways contributing to the rural-urban disparity in our outcomes.

It is thus not surprising that the VanderWeele 3-way decomposition found little evidence for a pure direct component of the total disparity for either neonatal or infant mortality. The fact that we also found little evidence for a total disparity could indicate either that there is really no disparity to speak of (a very unlikely scenario given the evidence in the literature), or that the

pure direct component that we removed (via adjusting for SES and socio-cultural factors as discussed above) was the major contributor to the total disparity. Neither scenario distracts from our primary interest in this study, which was to understand the contribution of skilled attendance at birth (the mediator) to these outcomes--and this would be seen mostly via the pure indirect and mediated interaction components.

Our most interesting finding was evidence that the pure indirect and mediated interaction components pulled the total disparity in infant mortality in opposite directions. In real-world terms, this suggests that, while not using skilled attendance does worsen infant mortality as expected, rural dwellers who use skilled attendance suffer worse infant mortality outcomes than expected. While our findings affirm the importance of skilled attendance for determining infant mortality outcomes, its effect appears to differ for urban and rural dwellers. It appears to matter, not only that a woman receives skilled attendance, but whether she receives it in a rural or urban facility.

This could be explained in two ways. Firstly, it could reflect differences in the quality of skilled attendance between rural and urban areas. Rural health facilities are generally under-resourced compared to urban ones in Ghana.[300] They are less likely to offer comprehensive obstetric care services including blood transfusions, surgical interventions for obstetric complications and resuscitation and advanced care for newborns with birth complications such as prematurity or asphyxia.[301,302] Often, accessing such services implies referral to a higher-level facility for rural dwellers and this, especially with the difficulties with transportation often encountered in rural areas, usually means a delay in receiving care. Such delays have been shown to be associated

with adverse outcomes for both mother and child. In urban areas, these services are much more readily available and arguably of higher quality.[178,303]

A second mechanism possibly at play may be that women in urban and rural areas seek skilled attendance under different circumstances. The low rates of skilled attendance in rural areas suggests that rural mothers may be seeking care late, or when they develop intrapartum complications.[78,304] The higher than mortality rates associated with such complications along with the general lack of capacity to provide advanced obstetric care in rural areas (discussed above) may be driving the higher than expected mortality rates observed among those who use skilled attendance in rural areas. In urban areas, on the other hand, seven out of 10 mothers delivered with skilled attendance, suggesting that using intrapartum care is the norm. This situation would allow the early detection and management of complications and together with the readier availability of advanced care in urban areas may underlie the positive impact of skilled attendance among urban mothers.

There are many reasons why rural dwellers would be less likely to seek skilled attendance for uncomplicated labor. Firstly, there is often a practical reason driving that decision. With the general sparsity of health facilities and personnel in rural areas in Ghana, coupled with the often-poor transportation networks in such areas, it is very likely that a woman may just complete labor before she has had the opportunity to reach a health facility. Even on reaching a rural health facility, she is not guaranteed to have qualified personnel and necessary equipment available and she may end up referred to another facility, thus further aggravating the delay in receiving appropriate care.[184,301,304,305]

Successive governments in Ghana have developed programs meant to ameliorate this situation. One of the latest is the community health planning and services concept (CHPS) which embeds community health nurses within communities to provide primary care and intervene in pregnancy and labor as a first line of care.[182] The government has also put in place measures meant to attract and retain personnel in rural areas. These interventions include the establishment of the Ghana College of Physicians and Surgeons to provide postgraduate medical training in Ghana. Doctors admitted to the college are required to have served at least a year in a rural area and are also sent to work in these places as part of their training. Those who already work there are obligated to return for a number of years after their training is completed. A similar regime exists for other health professionals such as nurses, midwives and pharmacists.[306,307]

Prior to the advent of the National Health Insurance Scheme (NHIS) in Ghana, affordability was a huge barrier to accessing care for many rural dwellers. Even with the advent of the scheme, which provides comprehensive healthcare coverage for the payment of a small annual premium, some financial barriers still remain. It has been suggested that some rural households can't afford even the relatively low premium rates.[45,62] Other financial factors still at play include the costs of transportation to and accommodation in the location of the health facility, which is often not in the same location they live in.[141] There is also a potential loss of income from work days spent in the hospital caring for relatives. The Free Maternal Health Module of NHIS waived premiums for pregnancy and birth-related care.[177,183] While some studies show it has improved utilization of healthcare services, it remains to be seen if it can bridge the gap in skilled attendance between rural and urban areas.

Another reason for the low uptake of skilled attendance in rural areas is the predominance of socio-cultural norms, which give preference to "natural" interventions such as herbal medicine, which are perceived as somehow inherently superior, over modern approaches.[308,309] Other norms discouraging the use of modern medicine in labor have to do with the concept of womanhood as a value in and of itself. In some places, it is seen as the ultimate mark of womanhood to undergo natural childbirth and thus seeking skilled care in labor diminishes a woman's social standing. In other settings, the woman may require the permission of her husband or other relatives before she can seek medical attention in labor. Such beliefs tend to be more predominant in rural areas mostly as a result of the lower overall level of education, especially for women.[82,251,310,311]

We also explored the hypothetical impact of providing skilled attendance at birth to all women in Ghana over the study period (via estimating the CDM). We found that such a measure could have actually worsen disparities in neonatal mortality (increasing the rural-urban gap by about 11 per 1000 live births). This reinforces the notion that urban women have a qualitative advantage (possibly due to the factors earlier discussed) over rural women when it comes to skilled delivery with skilled attendance at birth.

6.6.1 Limitations/Strengths of study

In interpreting the findings of this study, some important limitation must be kept in mind. Firstly, the validity of its findings depends on the quality of the underlying study data—and that data has some important shortcomings. Perhaps the most important of these is the relatively low sample size (considering the 20-year study period), which would tend to make our findings imprecise.

Though we did not formally assess this, the relatively wide confidence intervals around our estimates leads us to suspect so. The other limitations of our data are shared by all survey data.

While the systematic sampling methodology of the DHS is designed to make the sample as representative of the general population as possible, in this particular case, we only had data on children who were born within 5 years of each survey. The extent to which these children are representative of the entire population is unclear. That said, this issue should apply more or less equally to rural and urban children and as our interest was mainly in comparing the two groups and any resulting bias should be minimal.

Our study spanned 20 years and over such a long period, there is the potential for time-varying confounding due to changing trends in common causes of our mediator and outcomes. While we included fixed-effects terms for year of birth to account for secular trends in the outcome, we could not account for all potential sources of such confounding.

Also, as with all other survey data, there is some risk of potential misclassification due to differences in the way the survey questions were designed, and answers coded across different survey years.

The TMLE approach used in this study, while providing the advantage of being doubly-robust is still dependent on accounting for confounders, especially of the mediator-outcome relationship. Unmeasured confounding thus remains a threat to the internal validity of our estimates.

Despite its numerous issues, this study demonstrates the use of survey data in an innovative way to answer a policy-relevant question. Quality data sources tailor-made for answering such

questions are not readily available in low- and middle-income settings and so our ability to provide some useful conclusions using publicly available survey data is encouraging.

This study also provides a real-life example of the application of the VanderWeele 3-way decomposition method as well as the use of TMLE in mediation analyses.

6.7 Conclusions

In this study, we demonstrated that skilled attendance plays an important role in driving disparities in infant mortality and that its contribution is both from differences in its distribution between rural and urban areas, as well as differences in its effect on mortality between urban and rural areas. Our findings suggest that beyond the availability of skilled attendance services, attention should be paid in our policy planning efforts to the quality of healthcare services provided. As efforts are made to meet the sustainable development goal 3 on improving health outcomes as well as goal 10 on reducing inequalities, issues such as rural-urban disparities in mortality outcomes should be given more prominent consideration by policy makers.

7 SYNTHESIS AND CONCLUSIONS

The goal of this dissertation was to contribute to our understanding of the impact of the National Health Insurance Scheme of Ghana. Specifically it set out to evaluate the impact of the NHIS on healthcare utilization and early childhood mortality outcomes, to assess the impact of the NHIS on levels and trends in rural-urban disparities in early childhood survival, and to explore the role of healthcare utilization in driving rural-urban disparities in early childhood survival.

We found that the advent of the NHIS could be credited with a 10 percentage-point increase in antenatal care usage with the strongest effect concentrated among the richest and best educated women (15 and 16 percentage-point increases respectively). We also found an increase in skilled attendance of 6 percentage-points, again with the benefits concentrated among women of high SES, though this increase disappeared when the contribution of the Free Maternal Health program was taken out. We found no evidence that the policy affected either neonatal or infant mortality, either overall, or within categories of SES.

On the question of whether the NHIS policy has improved rural-urban disparities in early childhood mortality, we found as follows: There was a pre-NHIS rural-urban disparity in infant mortality of about 13 per 1000 live births to the advantage of urban dwellers but this was essentially erased in the post-NHIS period—via a narrowing of the rural-urban gap by about 17 infant deaths per 1000 live births. We could not detect a rural-urban gap in level or trends in neonatal mortality either before or after the policy was enacted.

From our examination of the role of skilled attendance in driving rural-urban disparities, we found that after accounting for socio-economic and cultural factors, the total rural-urban disparity in infant mortality was composed mainly of a pure indirect component of about 4 per

1000 live births and a mediated interaction component of about -4 per 1000 live births. These components acted in opposite directions suggesting that, while skilled attendance was an important contributor to disparities in infant mortality, rural dwellers who received skilled attendance had higher than expected infant mortality rates. We could not detect nor decompose the total disparity in neonatal mortality.

Thus, in summary, we found that the NHIS policy has improved antenatal care usage and skilled attendance in general though women of higher socio-economic status have benefited the most. It has not had any impact on neonatal or infant mortality rates overall, though it has improved rural-urban disparities in infant mortality. We further found that once socio-economic and cultural factors are accounted for, the contribution of skilled attendance to rural-urban disparities in infant mortality are due not just to differences in its distribution between rural and urban areas, but also to differences in its effect (possibly reflecting differences in the quality of services or in the types of people who use it) between urban and rural areas. Thus, reducing early childhood mortality requires not only improving access to skilled attendance, but also improving the quality of skilled attendance provided.

In the quest to deliver healthcare, many options are available to policymakers. The 2010 WHO World Health Report[24] discussed several approaches to health financing that have been proposed and/or used to achieve UHC. It noted that no single approach stands out as clearly superior to the others. The appropriateness of any particular approach depends on the specific context in which it is to be used. Thus, it is important to incorporate not only theoretical considerations, but also practical lessons from the actual experience of countries when planning and implementing new UHC reforms. In this light, the findings of this dissertation constitute important considerations to

keep in mind. While lessons learned from one scheme may not easily translate to other schemes without consideration of the particular features and specific circumstances of that scheme, certain broad implications of our findings on the NHIS may be concluded:

1. Improvements in intermediate measures may not necessarily translate into improvements in actual health outcomes. It is important to track health outcomes when monitoring and/evaluating UHC policies.
2. It is important to consider equity when monitoring/evaluating UHC policies as the equity implications such policies could extend beyond its effect on the broader population. This is especially poignant for those reforms that are tax-funded and thus, in effect paid for by the entire population.
3. In improving access to care, attention must be paid to the quality of care provided and not just the level of access to care.

As more and more countries adopt UHC reforms, and as the world as a whole, moves towards achieving the Sustainable Development Goals, the lessons from these studies should serve as a guide to plan, implement and evaluate policies to improve health outcomes for populations.

APPENDICES

4.1. STATA code for difference-in-differences models

```
/*
	_____________________________________________________________________________
	Program		:	difference-in-differences analyses
	Author		:	ONO
	_____________________________________________________________________________
	Notes		:
	_____________________________________________________________________________
*/
* global settings
version 13
set more off
set seed 1234
capture clear all

* initiate paths
quietly do "~/OneDrive - McGill University/Thesis/scripts/paths.do"

* initiate log
capture log close
log using "$logs/obj2_analysis2.log", replace

*_____________________________________________________________________________
* declarations
local covs i.matage_cat i.educlvl i.kidsex i.kidtwin i.kbord_cat ///
	i.urban i.wealthq

*_____________________________________________________________________________
* Checking pre-inervention trends

use "$cleandata/obj2_final.dta", clear

regress neodead c.kidbirthyr##treated if !pst [pweight = wt]
predict p1
sc p1 kidbirthyr if treated & !pst || sc p1 kidbirthyr if !treated & !pst, ///
 name(p1, replace) ///
 title("NMR") legend(label(1 "Treated") label(2 "Controls")) ///
 xtitle("Birth year") ytitle("Prob. of death")

regress infdead treated##c.kidbirthyr   if !pst [pweight = wt]
predict p2
sc p2 kidbirthyr if treated & !pst || sc p2 kidbirthyr if !treated & !pst, ///
 name(p2, replace) ///
 title("IMR") legend(label(1 "Treated") label(2 "Controls")) ///
 xtitle("Birth year") ytitle("Prob. of death")



use "$cleandata/obj2_anc_skilleddel.dta", clear
ta ancare ctry

regress ancare treated##c.kidbirthyr if !pst [pweight = wt]
predict p3
sc p3 kidbirthyr if treated & !pst || sc p3 kidbirthyr if !treated & !pst, ///
 name(p3, replace) ///
 title("ANC") legend(label(1 "Treated") label(2 "Controls")) ///
 xtitle("Birth year") ytitle("Prob. of death")


regress skdel treated##c.kidbirthyr i.country if !pst [pweight = wt]
predict p4
sc p4 kidbirthyr if treated & !pst || sc p4 kidbirthyr if !treated & !pst, ///
 name(p4, replace) ///
 title("Skilled Del.") legend(label(1 "Treated") label(2 "Controls")) ///
 xtitle("Birth year") ytitle("Prob. of death")
```

```
 grc1leg p1 p2 p3 p4, title("Pre-intervention trends in outcomes")
 graph export "$plots/pre_interv_manus.png", replace

*_____________________________________________________________________________
* functions

capture program drop lev_main
program define lev_main

        local rownames = ""
        regress `1' treated1 i.ctry_code i.pst i.kidbirthyr ///
                [pweight = wt], ///
                cluster(ctry_year)
        scalar b = _b[treated1]

        boottest treated1, bootcluster(ctry_year) nograph
        matrix ci = r(CI)

        matrix define res = (b, ci[1, 1..2])
        local rownames `rownames' main_`1'
        matrix rownames res = `rownames'
        matrix results = (results \ res)

end

capture program drop lev_results
program define lev_results

        local rownames = ""
        levelsof `2', local(levs)

        foreach level of local levs {
                regress `1' treated1 i.ctry_code i.pst i.kidbirthyr ///
                        if `2' == `level' [pweight = wt], cluster(ctry_year)
                scalar b = _b[treated1]

                boottest treated1, bootcluster(ctry_year) nograph
                matrix ci = r(CI)
                matrix list ci

                matrix define res = (b, ci[1, 1..2])
                local rownames `2'_`level'_`1'
                matrix rownames res = `rownames'
                matrix results = (results \ res)

        }

end

capture program drop lead_lag
program define lead_lag

        foreach pre in lead lag {
        regress `1' treated1 `pre'* i.ctry_code i.pst i.kidbirthyr ///
                [pweight = wt], ///
                cluster(ctry_year)

                forvalues i = 1/3 {
                        scalar b = _b[`pre'`i']

                        boottest `pre'`i', ///
                                bootcluster(ctry_year) nograph
                        matrix ci = r(CI)

                        matrix define res = (b, ci[1, 1..2])
                        local rownames `pre'`i'_`1'
                        matrix rownames res = `rownames'
                        matrix results = (results \ res)

                }
```

```
	}
end

capture program drop run_models
program define run_models
	matrix define results = (., ., .)


	foreach outc in `0' {
		 quietly lev_main `outc'

		foreach het in wealthq educlvl {
			quietly lev_results `outc' `het'
		}

		quietly lead_lag `outc'
	}

	matrix list results
	svmat2 results, rnames(outcome) full

end

program define run_models_2
	matrix define results = (., ., .)


	foreach outc in `0' {
		 quietly lev_main `outc'

		foreach het in wealthq educlvl {
			quietly lev_results `outc' `het'
		}
	}

	matrix list results
	svmat2 results, rnames(outcome) full

end

*_____________________________________________________________________________
* run models

use "$cleandata/obj2_final.dta", clear

egen ctry_year = group(country kidbirthyr)
run_models neodead infdead
keep results* outcome
drop if missing(outcome)
save "$output/obj1_results_neodead_infdead_main.dta", replace

use "$cleandata/obj2_anc_skilleddel.dta", clear
egen ctry_year = group(country kidbirthyr)
run_models ancare skdel
keep results* outcome
drop if missing(outcome)
save "$output/obj1_results_anc_skdel_main.dta", replace


use if kidbirthyr <= 2009 using "$cleandata/obj2_final.dta", clear
egen ctry_year = group(country kidbirthyr)
run_models_2 neodead infdead
keep results* outcome
drop if missing(outcome)
save "$output/obj1_results_neodead_infdead_restricted.dta", replace

use if kidbirthyr <= 2009 using "$cleandata/obj2_anc_skilleddel.dta", clear
egen ctry_year = group(country kidbirthyr)
run_models_2 ancare skdel
keep results* outcome
drop if missing(outcome)
```

```
save "$output/obj1_results_anc_skdel_restricted.dta", replace

*_____________________________________________________________________________
log close
exit
```

5.

5.1. Stata code for ITSA

```
/*
	_____________________________________________________________________________
	Program			:	ITSA analysis for impact of NHIS on rural-urban
						disparities in neonatal and infant mortality

	Author, date	:	ONO, May 4 2019
	_____________________________________________________________________________
	Notes			:

	Steps:
	1. Careful examination of the time plot of the series of interest
	2. Establish whether the series is trend or difference stationary in nature
	3. Assess the presence of autocorrelation
	4. Fit intervention models controlling for any autocorrelation
	5. Examine residuals from obtained models and assess adequacy
	6. Incorporate seasonal influences in models where required
	7. Check for any collinearity issues particularly when working with
		change in trend terms

	Input: IPUMS/DHS births data Ghana, 1993 - 2014
	Output:

	Neonatal: Qtr urban qtr*urban qtr*post qtr*urban*pst
	Infant: qtr urban post urban*post


	_____________________________________________________________________________
*/
* global settings
version 13
set more off
capture clear all

* initiate paths
quietly do "~/OneDrive - McGill University/Thesis/scripts/paths.do"

* initiate log
capture log close
log using "$logs/obj2_analysis2.log", replace

*_____________________________________________________________________________
* declarations


*_____________________________________________________________________________
* functions

* plot trends for outcomes by urban/rural
capture program drop plot_ts
program plot_ts
	args outcome outc_str urban urban_str

	tsline `outcome' if urban == 1 || ///
	tsline `outcome' if urban == 0 ||, ///
			yscale(range(0(0.01)0.05)) ///
			title("Rural-Urban trends in ", size(medium)) ///
				ytitle("Probability of `out_str' death", size(small)) ///
				xtitle("Quarter of birth", size(small)) ///
				xlabel(, labsize(small)) ///
				ylabel(, labsize(small)) ///
				tline(2004q1) ///
				name(`outc_str'_`urban_str', replace)
	graph export "$plots/`outc_str'_`urban_str'.png", replace

end

* combine plots for trends
```

```
capture program drop plot_comb
program plot_comb

	args outc outcstr

	plot_ts `outc' `outcstr' 1 urban
	plot_ts `outc' `outcstr' 0 rural

	graph combine `outcstr'_urban `outcstr'_rural, ycommon ///
		title("Trends in `outcstr' mortality in rural and urban Ghana", ///
			size(medium)) ///
		subtitle("By quarter from 1993 to 2013", size(small)) ///
		note("Vertical line denotes implementation of NHIS", size(small)) ///
		name(`outc'_combined, replace) col(1)
	graph export "$plots/`outc'_combined.png", replace

end


* check for stationarity, autocorrelation
capture program drop pre_analysis
program pre_analysis

	* check for stationarity
	dfuller `1' if urban == 1
	dfuller `1' if urban == 0

	* fit pre-specified model
	*regress `1' c.birthdateqtr##pst##urban /*i.qtr  L.`1'*/, robust
	poisson `1' c.birthdateqtr##pst##urban /*i.qtr  L.`1'*/, robust
		capture drop resid
		predict resid, residuals

	* check for autocorrelation in residuals
	local urb Urban Rural

	forvalues j = 0/1 {

		ac resid if urban == `j', name(neo_ac`j', replace) ///
			lags(20) title("`:word `=`j'+ 1' of `urb''") ///
			ytitle("Autocorrelations of residuals", size(small)) ///
			ylabel(, labsize(small)) xlabel(, labsize(medium))

		pac resid if urban == `j', name(neo_pac`j', replace) ///
			lags(20) title("`:word `=`j'+ 1' of `urb''") ///
			ytitle("Partial autocorrelations of residuals", size(small)) ///
			ylabel(, labsize(small)) xlabel(, labsize(medium))

		corrgram resid if urban == `j', lags(20)
	}

	* combine autocorrelation graphs
	graph combine neo_ac0 neo_pac0 neo_ac1 neo_pac1, ///
		title("Autocorrelation among model residuals", size(medium))

	*graph export "$plots/autocorrelation_`1'.png", ///
	*	replace
	graph export "$plots/autocorrelation_`1'_pois.png", ///
		replace

end

capture program drop main_its
program main_its
	local i 1
	/*
		Neonatal: Qtr urban qtr*urban qtr*post qtr*urban*pst
		Infant: qtr urban post urban*post
	*/
	#delimit ;
	local long_model =
```

```
		"qtr urban pst qtr_sq urban_qtr urban_pst pst_qtr " +
		"urban_pst_qtr urban_qtr_sq pst_qtr_sq urban_pst_qtr_sq";

	local model_rhs
		`" "qtr urban pst urban_qtr urban_pst pst_qtr urban_pst_qtr"
		"qtr urban pst urban_pst pst_qtr"
		"qtr urban pst urban_pst"
		"qtr urban urban_qtr pst_qtr urban_pst_qtr"
		"qtr urban urban_qtr pst_qtr"
		"`long_model'" "' ;
	#delimit cr


	foreach rhs of local model_rhs {

		regress `1' `rhs', robust
		margins, dydx(qtr) over(urban pst)

		/*
		predict fitted`1'`++i', xb

		tw sc `1' qtr if urban == 1 || sc `1' qtr if urban == 0 || ///
			tsline fitted`1'`i' if urban == 1 || ///
			tsline fitted`1'`i' if urban == 0, ///
			legend(label(1 "Urban (observed)") label(2 "Rural (observed)") ///
				label(3 "Urban (fitted)") label(4 "Rural (fitted)") ///
				symxsize(5) symysize(5) size(small)) ///
			note("model: `rhs'", size(vsmall)) ///
			name(model_`i', replace)

		graph export "$plots/fitted_trends_`:var lab `1''_`i'.png", replace
		*/
		*estat ic
		eststo model_`i++'

		/*regress L.`1' `rhs' /*i.qtr*/
		estat ic
		eststo model_`i++'

		regress `1' `rhs' i.qtr
		estat ic
		eststo model_`i++'
		*/
	}
	/*
	if inlist(`1', neo_pred, neo_pred_adj) {
		grc1leg model_2  model_5, cols(1) ///
			title("Neonatal mortality (best fitting/full models)", size(medium))
		*graph save nmr_fitted.gph, replace

		graph export "$plots/bestfit_`1'.png", replace

	}
	else if inlist(`1', inf_pred, inf_pred_adj) {
		grc1leg model_2 model_4, cols(1) ///
			title("Infant mortality (best fitting/full models)", size(medium))
		* graph save imr_fitted.gph, replace
		graph export "$plots/bestfit_`1'.png", replace
	}

	*/
	/*
	outreg2 model_1 model_2 model_3 model_4 ///
		using "$output/obj2_itsa_new2.csv", excel ci wide
	*/

end


*_____________________________________________________________________________
```

```
* load data
use "$cleandata/obj2_ts_data.dta", clear
*use "$cleandata/obj2_ts_poisson.dta", clear
gen quarter = quarter(dofm(qtr))

*_____________________________________________________________________________
*de

plot_ts inf_pred
*
/*
plot_comb neo_pred neonatal
plot_comb inf_pred infant
plot_comb neo_pred_adj neonatal
plot_comb inf_pred_adj infant
*/
*

*set trace on
*foreach outcome in neo_pred inf_pred neo_pred_adj inf_pred_adj {
foreach outcome in neo inf {
        *pre_analysis `outcome'
        pois_its `outcome'dead n_`outcome'
        *replace `outcome' = `outcome' * 1000
        *main_its `outcome'
        *esttab model_* using "$output/`outcome'_res_pois", ///
        *       b(%5.2f) ci(%5.2f) label aic bic ci wide nostar replace tab

                *pre_analysis `outcome'
        /*main_its `outcome'
        replace `outcome' = `outcome' * 1000
        main_its `outcome'
        esttab model_* using "$output/`outcome'_res3", ///
                b(%5.2f) ci(%5.2f) label aic bic ci wide nostar replace tab
        */
}

*_____________________________________________________________________________

log close
exit
```

6.
6.1. STATA Code for VanderWeele decomposition

```
/*
	_____________________________________________________________________________
	Program		:	Analysis for Obj 1
	Author		:	ONO
	_____________________________________________________________________________
	*/

* global settings
version 13
set more off
capture clear all

* initiate paths
quietly do "~/OneDrive - McGill University/Thesis/scripts/paths.do"

* initiate log
capture log close
log using "$logs/obj1.log", replace

capture log close obj1_long
log using "$logs/obj1_long.log", append name(obj1_long)

use "$cleandata/objective1_data.dta", clear

la define marstat 0 "Not in a union" 1 "In a union"
la val marstat marstat

la define ageat1stbirth 1 "< 15 yrs" 2 "15 - 18 yrs" 3 "> 18 yrs"
la val ageat1stbirth age1stbirth



*la define religion
/*
*tab2 del*
local c_my educlvl ethnicitygh wealthq ///
		religion ageat1stbirth marstat

foreach var of local c_my {
	table `var' urban, col

}

*tab2 del*
local c_my educlvl ethnicitygh wealthq ///
		religion ageat1stbirth marstat


tabout `c_my' urban using "$output/chp6_desc.csv", ///
	replace style(csv) c(freq col)
*/

*_____________________________________________________________________________
* define program

/*
Checklist to try:
1. no confounders
2. calculate weights by hand

*/

capture program drop cdm
program define cdm, rclass

	** exp-outc confounders
	local c_xy age
```

```
** exp-med confounders
local c_my wealthspline* i.educlvl i.kidbirthyr i.ethnicitygh ///
       i.religion i.ageat1stbirth i.marstat



*tempvars
tempvar Y X M I_xm I_x H H_star X_hat

* initialize variables
gen `X' = urban
gen `M' = prop_del
gen `Y' = kidead

gen `I_xm' = .
gen `I_x' = .
gen `H' = .
gen `H_star' = .


* main analysis

* models
* 1. Outcome model: predicting Q2_10
logit `Y' `X'##`M' `c_xy' `c_my' [pweight = denom_wt], nolog ///
       // iterate(1000) nolog
       estimates store outcome_model
       estimates title: "Outcome model"

* 2. Treatment mechanism/propensity scores
logit `X' `c_xy' [pweight = denom_wt], nolog ///
                    // iterate(1000) nolog
       estimates store treatment_model
       estimates title: "Treatment model"
       predict `X_hat'

* 3. Mediator mechansism
logit `M' `X' `c_xy' `c_my' [pweight = denom_wt], nolog ///
              // iterate(1000) nolog
       estimates store mediator_model
       estimates title: "Mediator model"

forvalues x = 0/1 {
       forvalues m = 0/1 {

              tempvar logit_Q2_`x'`m'  M_hat_`x' Q2star_`x'`m' ///
                     logit_Q1_`x'`m' Q1star_`x'`m'

              * 1. Outcome model: predicting Q2_10
              estimates restore outcome_model
                     replace `X' = `x'
                     replace `M' = `m'
                     predict `logit_Q2_`x'`m'', xb

                     bysort urban: su `logit_Q2_`x'`m''


              ** b) model for mediator
              estimates restore mediator_model
                     replace `X' = `x'
                     predict `M_hat_`x''
                     su `M_hat_`x'', meanonly
                     scalar E_M_`x' = r(mean)


              ** c) calculate fluctuation parameter
              replace `I_xm' = (urban == `x' & prop_del == `m')
              replace `I_x' = urban == `x'

              replace `H' = `I_xm'/((1 - `M_hat_`x'')*(`X_hat'))
```

```
                        * 3. 1st fluctuation step
                        logit `Y' `H' [pweight = denom_wt], ///
                                offset(`logit_Q2_`x'`m'') nocons ///
                                // iterate(1000)
                                predict `Q2star_`x'`m''

                        replace `X' = urban
                        glm `Q2star_`x'`m'' `X' `c_xy', ///
                                family(binomial) link(logit) ///
                                // iterate(1000)
                                replace `X' = `x'
                                predict `logit_Q1_`x'`m'', xb

                        replace `H_star' = `I_x/X_hat'
                        glm `Q2star_`x'`m'' `H_star', ///
                                offset(`logit_Q1_`x'`m'') ///
                                // iterate(1000)
                                predict `Q1star_`x'`m''

                                su `Q1star_`x'`m''
                                scalar EY_`x'`m' = r(mean)

                }
        }

        scalar cdm = EY_10 - EY_00
        scalar int_ref = (EY_11 - EY_10 - EY_01 + EY_00) * E_M_0
        scalar int_med = (EY_11 - EY_10 - EY_01 + EY_00) * (E_M_1 - E_M_0)
        scalar pie = (EY_01 - EY_00) * (E_M_1 - E_M_0)
        scalar pde = cdm + int_ref
        scalar tie = pie + int_med
        scalar TE = (EY_11*E_M_1 + EY_10*(1 - E_M_1)) - ///
                (EY_01*E_M_0 + EY_00*(1 - E_M_0))

        return scalar cdm = cdm
        return scalar int_ref = int_ref
        return scalar int_med = int_med
        return scalar pie = pie
        return scalar pde = pde
        return scalar tie = tie
        return scalar TE = TE
        return scalar E_M_1 = E_M_1
        return scalar E_M_0 = E_M_0
        return scalar EY_11 = EY_11
        return scalar EY_10 = EY_10
        return scalar EY_01 = EY_01
        return scalar EY_00 = EY_00


end

*cdm

*di r(cdm) + r(int_med) + r(int_ref) + r(pie)
*di TE

*_____________________________________________________________________________

** variables to select
local vars wealthspline* educlvl birthyrspline* ethnicitygh religion ///
        ageat1stbirth marstat age kidtwin interv idhsstrata idhspsu kidead ///
        urban prop_del denom_wt kidalive year kidagedeath kidbirthyr

*_____________________________________________________________________________
* neonatal mortality analysis

* load data
use  `vars' if interv > 1 & !missing(kidalive) & year > 1993 ///
        using "$cleandata/objective1_data.dta", clear
```

```
        *sample 20, by(kidbirthyr urban)

        * define neonatal death indicator
        replace kidead = kidalive == 0 & kidagedeath < 128

        replace denom_wt = denom_wt / 1000000

        table urban, c(mean kidead semean kidead)


*_____________________________________________________________________________
set seed 123
bs  ///
        tie             = (r(tie)) ///
        pde             = (r(pde)) ///
        pie             = (r(pie)) ///
        int_med         = (r(int_med)) ///
        int_ref         = (r(int_ref)) ///
        cdm             = (r(cdm)) ///
        TE                      = (r(TE)) ///
        E_M_1           = (r(E_M_1)) ///
        E_M_0           = (r(E_M_0)) ///
        EY_11           = (r(EY_11)) ///
        EY_10           = (r(EY_10)) ///
        EY_01           = (r(EY_01)) ///
        EY_00           = (r(EY_00)), ///
        reps(1000) : cdm

putexcel A1 = e* using "$output/obj1_results_all.xlsx", ///
        sheet("Neonatal") replace
/*
matrix A1 = e(b)
matrix B1 = e(b_bs)
matrix C1 = e(ci_percentile)
matrix D1 = e(ci_bc)
matrix E1 = e(ci_normal)
matrix F1 = e(ci_bca)

*matrix list A B C D E F
*matrix neo = A, B, C, D, E, F
*matrix colnames neo = neo_b neo_b_bs neo_ci_p neo_ci_bc neo_ci_norm neo_ci_bca

*/

*_____________________________________________________________________________
* infant mortality analysis

* load data
use  `vars' if interv > 12 & !missing(kidalive) & year > 1993 ///
        using "$cleandata/objective1_data.dta", clear

        *sample 20, by(kidbirthyr urban)

        * define infant death indicator
        replace kidead = kidalive == 0 & kidagedeath < 212

        replace denom_wt = denom_wt / 1000000

table urban, c(mean kidead semean kidead)

*_____________________________________________________________________________
* bootstrap CI estimates

set seed 123
bs  ///
        tie             = (r(tie)) ///
        pde             = (r(pde)) ///
        pie             = (r(pie)) ///
        int_med         = (r(int_med)) ///
        int_ref         = (r(int_ref)) ///
        cdm             = (r(cdm)) ///
```

```
        TE                      = (r(TE)) ///
        E_M_1           = (r(E_M_1)) ///
        E_M_0           = (r(E_M_0)) ///
        EY_11           = (r(EY_11)) ///
        EY_10           = (r(EY_10)) ///
        EY_01           = (r(EY_01)) ///
        EY_00           = (r(EY_00)), ///
        reps(1000) : cdm

putexcel A1 = e* using "$output/obj1_results_all1.xlsx", ///
        sheet("Infant") replace
/*
matrix A2 = e(b)
matrix B2 = e(b_bs)
matrix C2 = e(ci_percentile)
matrix D2 = e(ci_bc)
matrix E2 = e(ci_normal)
matrix F2 = e(ci_bca)

local let A B C D E F
forvalues i = 1/6 {
        forvalues j = 1/2 {
                putexcel A`=`i'*5+ `j'*50' = matrix(`:word `i' of `let''`j', names) ///
                        using "$output/chp6matrices1", modify
                matrix list `:word `i' of `let''`j'

        }


}

*matrix inf = A, B, C, D, E, F
*matrix colnames neo = inf_b inf_b_bs inf_ci_p inf_ci_bc inf_ci_norm inf_ci_bca
*/
*_____________________________________________________________________________
* save and export results

*matrix results = neo, inf
*putexcel A1 = matrix(results, names) using "$output/obj1_results_main1.xlsx", ///
*       sheet("Results") replace

*_____________________________________________________________________________
* end



exit
log close _all
```

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