The Effects of Family Planning Type and Prevalent Use on Fertility and Under-Five Mortality in Tanzania

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Margherita Emilia Ghiselli

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J. Michael Oakes, PhD

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Abstract

Current projections estimate that the population of Tanzania will triple by 2050, reaching 110 million. Voluntary family planning (FP) is the best strategy to curb population growth. However, contraception availability varies across regions. This study accounts for the regional context in which contraceptive choices – and reproductive outcomes – occur. Its research question, then, is: what is the effect of the regional context on total fertility rate and under-five mortality rate?

This study employs the 2010 Tanzania Demographics and Health Survey (DHS), a representative probability sample of 10,139 women ages 15 to 49. To mimic randomization, regions are matched on education, wealth, and urban-rural status, and assumed to be exchangeable save for their exposure to an FP method. The region-level independent effect of a specific FP method on total fertility rate and under-five mortality rate is calculated for different types of FP methods (i.e., oral contraceptives, injectables, condoms, sterilization, traditional methods). Also, population projections are re-calculated for incremental prevalence of each method.

Only permanent methods significantly reduce the total fertility rate, with an average causal effect of -1.59 children (-2.55, -0.65). Indeed, they alone guarantee the end of reproductive events. No method significantly reduces under-five mortality. Population growth trends would be most impacted by oral contraceptives (from 40 million in 2010 to 33 million in 2025 if prevalence increases by 19%), followed by injectables (42 million in 2025 with 19% prevalence increase). This
difference is due to continued use of oral contraceptives through a woman's twenties and thirties, while injectables are mostly used by women in their twenties. These results suggest that sterilization immediately impacts on a region's total fertility rate. However, long-term investments in oral and injectable contraceptives will have a significant impact reducing population growth, and should be given funding priority.
Table of Contents

Acknowledgements.....................................................................................................i
Abstract.......................................................................................................................ii
Table of Contents....................................................................................................iv
List of Tables...........................................................................................................vii
List of Figures.........................................................................................................viii
1. Introduction ............................................................................................................ 1
2. Background ............................................................................................................ 5
   2.1 Overview ......................................................................................................... 5
   2.2 Fertility and under-five mortality trends in Tanzania ..................................... 5
   2.3 Definition of family planning ...................................................................... 6
   2.4 Benefits of FP strategies ............................................................................. 7
   2.5 Contraceptive strategies ............................................................................. 8
   2.6 Current system of healthcare administration ............................................. 9
   2.7 Barriers to contraceptive use ...................................................................... 11
   2.8 Determinants of contraceptive use ............................................................ 15
   2.9 Gaps in the literature .................................................................................. 17
   2.10 Summary ................................................................................................... 20
3. Theoretical Framework ....................................................................................... 21
   3.1 Overview .................................................................................................... 21
   3.2 Ideal experiment ......................................................................................... 21
   3.3 Contextual effects ....................................................................................... 22
   3.4 Previous theoretical models ...................................................................... 23
   3.5 Specific Aim 1: Counterfactual causal framework ..................................... 26
   3.6 Specific Aim 2: Coleman's Social Theory framework ................................ 28
   3.7 Summary .................................................................................................... 32
4. Data Sources and Measures ................................................................................ 33
   4.1 Overview .................................................................................................... 33
   4.2 Demographic and Health Surveys ............................................................. 33
   4.3 Region-specific population projections ..................................................... 36
   4.4 Sample representativeness ....................................................................... 39
   4.5 Unmeasured confounding ......................................................................... 40
   4.6 Missing values ........................................................................................... 40
   4.7 Summary .................................................................................................... 41
5. Validation of DHS items ..................................................................................... 43
   5.1 Overview .................................................................................................... 43
   5.2 Background ................................................................................................. 43
   5.3 Methods ....................................................................................................... 45
      5.3.1 Study design ....................................................................................... 45
      5.3.2 Target population ............................................................................... 45
      5.3.3 Recruitment ....................................................................................... 46
      5.3.4 Focus groups ..................................................................................... 47
      5.3.5 Questions .......................................................................................... 48
      5.3.6 Analysis ............................................................................................ 51
7.3.3 Under-five mortality ............................................................... 117
7.3.4 Regional context specification ........................................ 118
7.4 Specific Aim 2 ................................................................. 125
  7.4.1 Number of births predicted, by FP method .......... 125
  7.4.2 Number of under-five deaths predicted, by FP method 133
  7.4.3 Population projection 2010-2025 under different FP scenarios 140
7.5 Sensitivity analysis ......................................................... 146
7.6 Summary ................................................................. 153

8. Discussion ................................................................. 154
  8.1 Overview ................................................................. 154
  8.2 Summary of findings .................................................. 154
  8.3 Specific Aim 1 ............................................................. 156
    8.3.1 Current literature ............................................... 156
    8.3.2 Fertility ............................................................ 157
    8.3.3 Under-five mortality ........................................... 159
  8.4 Specific Aim 2 ............................................................. 161
    8.4.1 Current literature ............................................... 161
    8.4.2 Oral contraceptives ............................................. 163
    8.4.3 Barrier methods ................................................ 166
  8.5 Sensitivity analysis ..................................................... 169
  8.6 Hypothetical counterfactuals ........................................ 172
  8.7 Strengths and limitations ............................................ 175
    8.7.1 Limitations .......................................................... 175
    8.7.2 Strengths .......................................................... 177
  8.8 Recommendations .................................................... 179
    8.8.1 Future research .................................................. 179
    8.8.2 Policy implications .............................................. 181
  8.9 Conclusions ............................................................ 183

9. Bibliography ............................................................... 185

Appendix A. Geopolitical map of Tanzania ......................... 194
List of Tables

Table 6.1 Family planning groupings, based on each method's advocacy strategy, effectiveness and medical requirements..............................70

Table 7.1 Weighted sample description, across region of residence and maternal age group.........................................................................101

Table 7.2 Types of family planning methods, with weighted frequency and proportion of use.........................................................................103

Table 7.3 Distribution of family planning methods' prevalence of use, by maternal age group (row %).............................................................................105

Table 7.4 Weighted frequency and proportion of the sample's educational attainment (primary school completion: yes/no), urban/rural status, occupation (farmer: yes/no), and average wealth index value, stratified by family planning method.................................108

Table 7.5 Total fertility rates and under-five mortality rates, by regions of Tanzania.........................................................................................110

Table 7.6 Average causal effect of different family planning methods on fertility, for different model specifications........................................121

Table 7.7 Average causal effect of different family planning methods on under-five mortality, for different model specifications........................................124

Table 7.8 Weighted distribution of family planning methods' prevalence, in the full sample and the sub-sample..............................................147

Table 7.9 Average causal effect of family planning methods on fertility, for the sample's subgroup where privacy was enforced during the DHS interview.................................................................150

Table 7.10 Average causal effect of family planning methods on under-five mortality, for the sample's subgroup where privacy was enforced during the DHS interview.................................................................152
List of Figures

**Figure 3.1** Representation of Coleman's "bathtub" for Specific 
Aim 2.......................................................................................................................31

**Figure 6.1** Analytic strategy for each model designed to answer 
Specific Aim 1.........................................................................................................83

**Figure 7.1** Weighted number of births in the sample during the 
36 months prior to the DHS interview, by maternal age group.........................112

**Figure 7.2** Weighted number of under-five deaths in the sample 
during the 60 months prior to the DHS interview, by maternal 
age group................................................................................................................114

**Figure 7.3a-e** Number of births accrued in 36 months given 
different proportions of family planning use, stratified by 
maternal age group. The first column of each group represents 
the number of children born under the current family planning 
prevalence of use, while the last column represents the number 
of children born if the age-specific prevalence of use were 
increased by 19%. The intermediate columns represent increases 
of 1%, 2%, 7%, and 12%, respectively.....................................................................130

**Figure 7.4a-e** Number of under-five deaths accrued in 60 
months given different proportions of family planning use, 
stratified by maternal age group. The first column of each 
group represents the number of deceased children under the 
current family planning prevalence of use, while the last 
column represents the number of children born if the 
age-specific prevalence of use were increased by 19%. 
The intermediate columns represent increases of 1%, 
2%, 7%, and 12%, respectively................................................................................137

**Figure 7.5a-e** Population projection for Tanzania from 2010 to 
2025, by different types and prevalence of family planning.........................143

**Figure 8.1** Proportion of oral vs. injectable contraceptive users, 
by maternal age group............................................................................................165
1. Introduction

Current projections estimate that the population of Tanzania will triple by 2050, reaching 110 million, if current population trends remain unchecked. The World Health Organization considers voluntary family planning (FP) to be the best strategy to curb population growth. However, contraception availability is limited in Tanzania. The country's reduced healthcare resources and poor road infrastructure do not allow healthcare providers to consistently offer a wide range of contraceptive options. Also, the use of a particular contraception method depends on the degree of perceived harm that the method may bring to the user, as well as the constraints placed on FP users by a conservative social context. This combination of limited resources, personal preferences, and social pressures produces a skewed mix of contraceptive methods that cannot satisfy the growing demand for contraceptives. It is necessary to identify the factors that influence individual family planning choices – and subsequent fertility outcomes – given the context in which these choices are made.

- Research question: The research question this study addresses is whether the region-specific total fertility rate and under-five mortality rate would change if different social and environmental conditions determined: a) which FP methods were available in each region; and b) in what proportion.

- Specific aims: To answer the research question, this dissertation has two specific aims:
  1. Assess the independent effect of each FP method on the total fertility rate (TFR) and the under-five mortality rate.
2. Re-estimate population projections of Tanzania between 2010 and 2025 for different contraceptives and different prevalence of use.

- **Theoretical framework**: We employ the counterfactual causal framework in Specific Aim 1. This framework requires that units of analysis be exchangeable on all factors except for the exposure of interest. To do so, we match regions on social and environmental characteristics (i.e., educational attainment, average wealth index value, urban status). Then we can estimate the independent effect of each FP method on fertility and under-five mortality events. We employ Coleman's multi-level theoretical framework in Specific Aim 2. This framework states that societal changes are grounded in individual actions. Therefore, we assess the association between each FP method and fertility and under-five mortality events at the individual level. Then we can create summary estimates of population projections under different FP scenarios.

- **Data sources**: We will employ three data sources:
  - The 2010 iteration of the Tanzania Demographics and Health Surveys (DHS)
  - Region-specific population projections for each region between 2002 and 2025, estimated by the Tanzania National Bureau of Statistics
  - Qualitative data we collected in Tanzania during July and August, 2010.

We use the first data source to answer both of the specific aims, while the second source is employed only in Specific Aim 2. The third data source consists of qualitative data on FP use, collected in focus groups from village women. We use these data to evaluate the validity of DHS items on FP by assessing: 1) the respondents' level of item comprehension; and 2) whether answers incorporate social desirability bias.
• **Outcome variables:**
  - Specific Aim 1 employs region-specific measures of total fertility rate (TFR) and under-five mortality rate
  - Specific Aim 2 employs individual-level count measures of fertility (i.e., number of births that occurred in the 36 months prior to the DHS interview) and under-five mortality (i.e., number of children younger than five who died in the 60 months prior to the DHS interview).

• **Exposure variables:**
  - Specific Aim 1 employs region-specific prevalence data for the contraceptive method currently in use.
  - Specific Aim 2 employs region-specific prevalence data for the contraceptive method currently in use, stratified by maternal age group.

• **Significance:** Previous studies estimate population growth trends assuming universal FP coverage. However, current infrastructures and social constraints make this spike in contraceptive use unlikely. Costs, staff training, and logistical considerations prevent providers from promoting all FP methods equally to all their patients. Nonetheless, it is necessary to reduce the skew of the methods mix currently available, so women can select the FP options that fit their reproductive goals. The contribution of this dissertation is the estimation of future population projections under different scenarios of FP type and prevalence. Researchers can select the scenario that most closely depicts the factors present in their region of interest, identify social and environmental elements that are
amenable to change, and design efficient interventions that improve FP use within that context. Specifically, this dissertation can inform interventions in:

– Public health, by calculating the FP type and prevalence needed to significantly reduce fertility and under-five mortality under different conditions.

– Public policy, by assessing the most effective FP methods to curb fertility and under-five mortality. Both national and international organizations can use this information to set regulatory measures and funding priorities to increase the availability and use of the most promising contraceptive methods, according to the needs and conditions in each region.

– Applied economics, by estimating the population size under different FP conditions. This, in turn, informs the planning and development of future health, education, employment, and travel resources and infrastructures.

– Sociology, by assessing the social ramifications of increasing FP availability in rural communities. Of potential interest is whether increased use of FP strategies impacts the role of women as decision makers of their own fertility options.
2. Background

2.1 Overview

Population reduction in Tanzania is at a standstill, despite years of research, policy implementation, and health interventions. It is necessary to review the current literature and identify areas of further study. In this chapter, We present the current total fertility rates and under-five mortality rates in Tanzania, define family planning and its goals, describe the barriers to contraceptive use that currently exist in the country, assess changes in fertility preferences and the factors behind these changes, and finally review the gaps in the fertility literature.

2.2 Fertility and under-five mortality trends in Tanzania

Current projections estimate that the population of Tanzania will triple by 2050, reaching 110 million, if current population trends remain unchecked (UN, 2010). The population already quadrupled since independence in 1961 – reaching 38 million in 2005. While there has been some modest success in fostering population control (Sedgh et al, 2007; Hinde et al, 2000), today this trends seems to have stalled. The population growth rate has remained stagnant at 6.7% per year since the late 1990s (Feyisetan et al, 2000; Garenne et al, 2008; Westoff et al, 2001), and the under-five mortality rate remains fixed around 91 per 1,000 live births (DHS, 2010).

These fertility trends match those of most Sub-Saharan countries (Ezeh et al, 2009). Yet Tanzania should be better off compared to its neighbors. The literature suggests a strong association between education and falling fertility rates. More highly educated persons use effective contraceptive methods more frequently, have their first child at a
later age, space their pregnancies farther apart, and consequently have fewer children than persons with a lower educational attainment (Kravdal et al, 2001; Larsen et al, 2003; Marchant et al, 2004). Tanzania has invested heavily in primary education since independence, and coverage is nearly universal for both boys and girls (UNICEF, 2008; Soares, 2007). Its fertility rates, however, have stalled to an average number of six children per woman (Ezeh et al, 2009; Garenne et al, 2008). This paradox suggests that educational attainment is only one of many factors – in both the individual and social spheres – that influence a woman’s fertility. To understand current population trends, we must first define the social context in which women make their reproductive choices. Once we identify the context-specific factors that promote some contraceptive methods over others, we can better explain both individual choices and the fertility trends that result.

2.3 Definition of family planning

As a response to this population stall, local and international agents promote the concept of family planning (FP) as a means to foster both population control and reproductive health rights. This notion took hold in 1972, when the World Health Organization defined FP as a strategy to "allow individuals and couples to anticipate and attain their desired number of children and the spacing and timing of their births. It is achieved through use of contraceptive methods" (WHO, 2010). In 1994, emphasis on world-wide FP was kindled at the United Nation's International Conference on Population and Development in Cairo, Egypt. Informed and free access to FP was listed as one of the four goals on the United Nation's agenda for international development
(ICPD, 1994). In 2000, the Millennium Development Goals included universal access to reproductive health by 2015 as part of Goal 5 (MDG, 2000).

The novel component of these calls to action is the voluntary nature of fertility reduction. Governments and colonial powers spent decades trying to control population growth to reduce demands on scarce supplies and services, and to simplify administrative tasks (World Bank, 2007). The WHO, instead, emphasizes fertility control as a reproductive right, where couples choose the number of children to have and consistently implement FP strategies (WHO, 2010).

2.4 Benefits of FP strategies

Correct and consistent use of contraceptives can dramatically reduce the number of unwanted pregnancies (Norton, 2005; Rafałimanana et al, 2000; Rutstein, 2005; Yeakey et al, 2009). Also, spacing pregnancies by 24 months or more can offer considerable health benefits to both mother and child. Infant mortality rates appear to decline as birth intervals become wider (Ikamari, 2000). Conversely, many avoidable stillbirths and perinatal deaths are due to premature deliveries and congenital malformations, caused by maternal depletion syndrome. This condition affects mothers whose folate levels have been depleted by previous close-spaced pregnancies (Hinderaker et al, 2003a). Also, mothers are at increased risk for perinatal death if they already have six or more children (Hinderaker et al, 2003b), a common situation in Tanzania.

Limiting and spacing pregnancies greatly contribute to the reduction of infant and childhood deaths because: 1) fewer children are born in the first place; 2) more resources are available to each child; and 3) mothers have time to regain their strength before
starting another pregnancy, thus increasing the proportion of children who survive to their fifth birthday. In the long term, FP also spearheads a country's development in women's education and household economics because women have more time to pursue their own goals before and during motherhood (LeGrand et al, 2002; Mulder et al, 2009). The growing economies of Asia and South America already experienced population transitions through the successful implementation of FP strategies on a large scale. Now they are reaping the benefits of a more educated populace and fewer demands on resources (Singh et al, 2009; Westoff et al, 2001; Ezeh et al, 2009).

2.5 Contraceptive strategies

Family planning strategies encompass both abstinence (complete or periodical) and contraceptive methods. The former is required of unmarried women in many societies, while it is difficult to implement among married women. While it is the only FP strategy that eliminates the possibility of pregnancy, numerous studies argue against abstinence-only interventions. In many cases, abstinence-only curricula contain scientifically inaccurate information and promote gender stereotypes. Several systematic reviews and cohort data from population-based surveys found little evidence of efficacy, as well as evidence of possible harm (Ott et al., 2007). Local and international organizations interested in comprehensive FP interventions prefer to promote contraception methods alongside abstinence.

Contraceptive methods divide themselves in two categories: modern and traditional. Modern methods are contraceptives whose effectiveness in reducing the probability of conception has been clinically proven. These are: male sterilization, female sterilization,
male condoms, female condoms, injectable hormone-based contraceptives (e.g., Depo Provera), combined oral contraceptive pills (also known as "the pill"), intra-uterine devices (IUD), and hormone-releasing contraceptive implants (e.g., Norplant). These methods can be obtained free of charge or for a fee at the local government clinic, private clinic, hospital, pharmacy, medicine shop (i.e., a store where over-the-counter pharmaceutical products are sold without the supervision of a pharmacist), mobile clinic (i.e., a vehicle sponsored by non-profit organizations that comes periodically to a village to visit patients and distribute medicine), or from community health officers. Traditional methods, instead, are FP strategies whose effectiveness has not been proven in clinical trials. These methods are part of the traditional lore passed on to younger generations by their older female relations. They include: withdrawal, lactational amenorrhea (i.e., prolonged breastfeeding), periodic abstinence, and strategies that involve medicinal herbs or water. Both users and clinicians recognize that these methods are sub-optimal in preventing pregnancies, but they are still attractive options in many villages because they do not require money, traveling, or medical consultation (Sedgh et al, 2007; Sullivan et al, 2006).

2.6 Current system of healthcare administration

To understand how health services and resources are distributed in Tanzania, it is necessary to describe the decentralized system of government. The country is currently divided into 26 regions and 118 districts (see Appendix A). All have some form of politically decentralized government (Gilson et al., 1994; World Bank, 1999). The goal of decentralization is to allow "the local government authorities [to] be free to make policy
and operational decisions consistent with government policies without undue interference by the central government institutions" (Ngwilizi, 2001).

Local governments are responsible for delivering basic health services at the district hospital level and below. Currently, local governments are, at least nominally, the employers of health workers, although all health workers must be selected and approved centrally. Local governments have little say in who is hired, disciplined, or rewarded (Gilson et al., 1994; World Bank, 1999).

Decentralized governments manage two budgets for their health expenditures. The development budget includes vertical programs, civil works, and donor projects. It is almost entirely centrally funded. The recurrent budget, instead, is about 70% centrally funded. The remaining 30% is raised through local taxes, licenses and fees, user charges, rental income from council properties, government grants, and government donations. User charges were instituted in the early 1990s, but have made only minor contributions to overall revenues (World Bank, 1999). Therefore, local health services must depend on donors' priorities and local resources for a large portion of their budget. However, donor priorities may not be in line with the health needs of local communities. Also, local health funds can oscillate considerably due to droughts or competing funding demands. These conditions create disparities in healthcare infrastructures across regions. Furthermore, decentralization has not been uniformly implemented across Tanzania. A 2002 survey from Measure Evaluation (the same organization that collects data for the Demographic and Health Surveys) found that fewer than half of the districts completed the decentralization process. The remaining areas find themselves at different points of
transferring administrative and fiscal responsibilities from the centralized administration to the local governments (Hutchinson, 2002). Therefore, healthcare administration and provision varies greatly across regions of Tanzania.

2.7 Barriers to contraceptive use

Women interviewed in previous studies report very high knowledge levels around FP. Indeed, 96% report they know of at least one modern contraceptive method. However, approximately 71% of women do not use any contraceptive, regardless of their desire to postpone or avoid a pregnancy by at least two years (DHS, 2010). Personal, social, and environmental barriers to FP use create a skewed contraceptive methods mix, where only a few methods are available to the public regardless of the market’s demand. This mix varies considerably across regions, since different areas have different combinations of constraints on FP use. These restraints vary from environmental limitations to personal preferences.

First, much misinformation surrounds modern contraceptive methods. Concerns range from cancer to heavy bleeding to general weakness. There is no consistent association between a method and a host of symptoms. Rather, in different communities, different methods are associated with different side effects. Nonetheless, all modern methods are associated with at least one side effect, and potential users may be hesitant to use them (Sedgh et al, 2007; Campbell et al, 2006). The root of this misinformation is unclear, but it probably originates from the combination of incomplete health education training, traditional lore, the association of unfamiliar procedures to any malaise, and rumors of other women experiencing side effects.
Second, high parity holds considerable value among Tanzanian families (Samir et al., 2007; Mwageni et al., 2001). Children are very valuable in Sub-Saharan communities because they tend to the livestock, help in the fields, and perform a myriad of household chores. Also, parents expect their children to support them completely once they reach old age. However, famines and disease kill many children before they reach adulthood. While the impact of these conditions has greatly diminished in the last decades, the "famine mentality" still lingers. Older Tanzanians want their community to have as many children as possible to safeguard themselves against future shortages. This desire negatively impacts their attitude towards contraceptive use – regardless of who is the actual contraceptive user. Contraceptive use is often seen as a direct threat to a family. A woman's use of contraceptives may be perceived as a rebellion against her husband's family. By denying him children, she may be viewed as shirking her duties as a wife. Therefore, contraceptives often carry a negative connotation because they threaten the current and future status of the family.

Third, even if FP is discussed among couples, most men either explicitly forbid their wives to use contraceptives or refuse to discuss the matter (Bunce et al., 2007; Greene et al., 2000; Plummer et al., 2006; Mwageni et al., 2001). This is especially true in rural areas, where traditional attitudes prevail and women have less bargaining power. When conversations do occur, women report that they often are brief, generic, and devoid of specific decisions (e.g., desired number of children, length of spacing between pregnancies, economic considerations, etc.). Women are often left to infer that all men are against FP.
Fourth, high parity reflects abeyance to religious tenants of fertility – whether they be Christian, Muslim, or based on traditions of ancestor worship (Hollos et al., 2004). Children often are seen as a gift from God or a duty to the ancestors. To reduce one's fertility through any means can be considered equivalent to refusing God's or the ancestors' will. Conversely, high parity carries substantial social capital because both the man and the woman are seen as fulfilling their duty towards the congregation. This status influences the social connections and religious life of many Tanzanians (Hollos et al., 2004; Keefe, 2006).

Fifth, overt contraceptive use likely will upset the husband, the family, and the congregation. The consequences of being discovered range from scolding to beatings to repudiation. Therefore, a woman may have to act in secret for fear of being discovered. This condition shapes a woman’s approach to contraceptive, her criteria for selecting a method, and her adherence to the prescribed regimen (Marchant et al., 2004). For example, injectable contraceptive is a popular method because it rarely leaves noticeable marks and does not require frequent doses (Sedgh et al., 2007).

Sixth, urban status is a major determinant of FP use. Numerous studies reported that contraceptive use in a location is inversely related to that location's distance from major traffic routes and large urban settlements (Chen et al., 2003, Arends-Kuenning et al., 2007). Distance, in terms of both time and space, determines the number and qualifications of local healthcare providers. Few want to live in such rural areas without electricity or running water. Therefore, most rural villages are the ones with the fewest healthcare staff members. Lack of specific medical training on FP may negatively
influence the use of many effective contraceptive methods, and allow misinformation around contraceptives to continue unchecked.

Seventh, FP availability is seriously curtailed by stock-outs: the demand for one or more contraceptive methods cannot be fulfilled because of limited inventory and infrequent re-stocking. This event occurs most frequently in remote villages. Local clinics seldom have the facilities to store temperature-sensitive medications, or the funds to stock all contraceptive methods. Therefore, the only contraceptive methods available in a village clinic may be those that can be stored in a cupboard for long periods of time without much expense. These usually are oral contraceptives, barrier methods, and injectable contraceptives. Therefore, the remoteness of a village heavily influences the range of reproductive health choices offered (Chen et al, 2002; Speizer, 2000a; Hinderaker et al, 2003b).

Eighth, mobile clinic visits are infrequent, often unscheduled, and short. Village clinics are not equipped to provide the more invasive FP procedures (i.e., sterilization and implants), so the brunt of these procedures falls on the staff of the mobile clinics. Between patient visits and emergency procedures, they seldom have enough time to implement permanent and semi-permanent contraceptive strategies or thoroughly educate users on how to employ modern methods (Speizer et al, 2000b).

Last, cost can be prohibitive. Approximately 97% of Africans are unwilling to pay the full cost of modern contraceptive methods. Indeed, a previous study suggests that people are willing to pay up to 1% of their disposable income for contraceptives (Cleland et al., 2006). Government clinics dispense their services for a very small fee. However,
household wealth may be so constrained by competing demands that any price for FP methods could be considered too onerous.

2.8 Determinants of contraceptive use

Despite these barriers, fertility preferences are starting to shift. Qualitative studies conducted in the country report a growing desire for smaller family sizes. Some Tanzanians, especially the urban-dwelling younger couples, wish to limit their overall number of children to two or three (Hollos et al., 2004). Most couples would prefer to space pregnancies farther apart instead of limiting the number of pregnancies (Feyisetan et al., 2000; Garenne et al., 2008; Glaser et al., 2006; Cleland et al., 2006). This preference is an attempt to maintain traditional conventions while improving a family's overall living conditions. The reason for this shift is due to the inability of many parents to provide the necessary nutrition, education, and health services to all their children. It is expensive to raise children in urban areas because of higher school fees, more expensive foodstuffs, and increased household expenditures. Also, living quarters are much smaller than in the countryside. Instead of being able to construct a dwelling anywhere on the village grounds, urban settlers must confine themselves to one- or two-room houses and share small courtyards with their neighbors. Furthermore, the community interconnectedness that distinguishes village life disintegrates in the cities. Most persons work outside the home, and no one is available to care for children during the day time. Maternal health and household economic development also are considerations in their family size preference (Clements et al., 2004; Hollow et al., 2004; Greene et al., 2000; Kravdal et al., 2001; Larsen et al., 2003).
Hence, demand for contraceptives is on the rise in Tanzania (Ezeh et al., 2009; Feyisetan et al., 2000; Westoff et al., 2001; Cleland et al., 2006). A review of the literature on FP in East Africa identifies three factors that shape the fertility preferences of FP users towards smaller families. These are socio-economic status (SES), cultural aspects, and location of residence.

Socio-economic status is a major determinant of FP use. It encompasses many individual and household characteristics, such as property, assets, dwelling characteristics, and cash. For example, fertility is strongly dependent on the household's economic and social context, as well as on a woman's general status within the household. The higher a woman's position in society, the longer she can postpone her first birth and focus on her own priorities (Kravdal et al., 2001; Habib, 2008; McTavish et al., 2010). Finally, household and individual wealth is directly related to the amount of disposable income that can be devoted to contraceptives (Cleland et al., 2006).

Cultural characteristics also are associated with fertility rates. The amount of time and resources invested in children's – especially girls' – education varies across regions of the country. Educational attainment is higher in Northern Tanzania compared to the South. Parity distribution across the country mirrors this educational divide (Hollos et al., 2004). Also, Christians report fewer children than Muslims, more willingness to consider FP, and greater use of contraceptives. Reported reasons are the absence of polygamy and the congregation's active encouragement to pursue a modern lifestyle. These elements contrast with the more traditional Islamic way of life (Hollos et al., 2004; Tengia-Kessy et al., 2006; Keefe, 2006; Agadjanian et al., 2009). Higher education and adherence to the
Christian faith also are determinants of "compagnable" marriages, where couples make reproductive decisions jointly (Hollos et al., 2003; Kravdal et al., 2001; Larsen et al., 2003). Finally, relatives and community member have a strong role in shaping a couple's desired family size and attitudes towards FP. The more conservative the social context, the greater are the external pressures for high parity and opposition to some, or all, FP methods (Mwageni et al., 2001).

Finally, the district of residence determines whether a household is an agricultural/pastoral one or if it relies on commerce, how much funding is invested in the children's education, and the degree of connectivity between urban centers and villages. Northern districts are generally better educated and more gainfully employed than the Southern ones, due to the high-volume traffic of tourists and non-governmental organizations in the Serengeti and Kilimanjaro areas (Keefe, 2006). Therefore, the social context is more permissive towards FP strategies in the northern regions compared to the southern ones. Fertility trends may be more prone to change there.

2.9 Gaps in the literature

Family planning research in Tanzania has been ongoing since before the country's independence in 1961. However, stagnant nativity rates indicate that efforts in this area are failing to make a significant impact on women's use of FP strategies. A review of the literature reveals some gaps in the research questions and methodology of previous studies. These gaps, in turn, may impact the design and implementation of FP interventions aimed at reducing fertility and under-five mortality in Tanzania.
• We could find no experimental studies that compare different types of FP methods against one another to assess which one impacts fertility and under-five mortality the most. Such a trial would require women to be randomly allocated to different contraceptives, and their fertility and under-five events measured across time. Implementing such a design would have been challenging, necessitating a large sample of women and sustained effort to retain the sample over time to ensure adequate statistical power. This is especially difficult in Tanzania, where FP service and delivery systems would need to be strengthened before they can be fully relied upon. Therefore, we have no comparison information on the independent effect of each FP method on fertility and under-five mortality events. This dissertation fills this gap: it estimates the effects of each contraceptive using observational data within an experimental framework.

• Many studies use DHS data to conduct analyses on FP strategies at the country level. However, Tanzania encompasses a great variety of ethnicities, languages, histories, mores, and occupations within distinct geographical regions (Lawrence, 2010). This regional context creates pressures on contraceptive users in the form or misinformation, overt or assumed prohibition to use an FP strategy, and limited financial resources to purchase contraceptives. Also, environmental factors – such as road conditions, contraceptive availability, and distance from clinic – further shape a person’s FP options. Therefore, contraceptive choices represent a compromise between social conventions, traditions, side effects, and environmental constrains. Previous studies often ignored this heterogeneity in favor of country-wide averages. Alternatively, they focus on the small area where the study took place. The resulting fertility and under-five mortality estimates
do not separate the effect of contraceptive use from that of different regional contexts. Specific Aim 1 of this dissertation, instead, assumes that the regional context perfectly predicts a woman's selection of a contraceptive method. The regional context is now the exposure to be administered. This way, we can assess the independent effect of each FP method on the total fertility rate (TFR) and the under-five mortality rate.

- Previous studies attempted to predict population projections after adjusting the estimates by contraceptive use. However, in these scenarios, FP coverage is often assumed to be universal (Singh et al, 2009), or all contraceptive types are considered together (Westoff, 2006; Ezeh et al., 2009). These parameters may be useful for model development, but they do not correspond to the reality on the ground. First, to achieve 100% FP coverage in the foreseeable future is highly unlikely. It would require a major overhaul of the country's transportation, medical, and educational infrastructures, as well as a major implementation of Tanzanians' reproductive goals at the national level. Second, the distribution of a contraceptive method's prevalence can be very different from that of another method, due to its efficacy, the advocacy that surrounds its recommendations, and the social and environmental context in which use takes place. If estimates are to be accurate, population growth trends must account for realistic ranges in the proportion of contraceptive use. Specific Aim 2 of this dissertation re-estimates population projections of Tanzania between 2010 and 2025 for different contraceptives and different prevalence of use. This way, we can estimate future population trends under different realistic FP scenarios.
• The DHS data may incorporate unknown biases that are specific to the culture and social structure of Tanzania. The survey is highly standardized for cross-country comparison, and therefore may not capture variations that are unique to the country. It is necessary to consult women themselves – in a less formal, more relaxed way – to assess whether the DHS questionnaire for FP in Tanzania is being understood and answered as intended. To date, few studies directly ask Tanzanian women for their opinions on contraceptive use. For this reason, we conducted focus groups in seven villages. Results suggest that answers are susceptible to social desirability bias, where respondents give socially acceptable answers to conform to expectations – regardless of their true behavior. This is most likely to occur when interviews are not conducted in private (see Section 5 for a full description of this sub-study). The sensitivity analysis conducted for this dissertation compares estimates from Specific Aim 1 with those obtained from a sub-sample of respondents who reportedly were interviewed in private. This way, we can assess the presence and magnitude of this bias, and interpret the results from Aim 1 in light of these discrepancies – if any.

2.10 Summary

In summary, this chapter identified gaps in the literature that this dissertation addresses. Further, it assessed the individual, social, and environmental factors that restrict contraceptive availability and use for women. These factors compose the regional context in which fertility choices are made. They are incorporated in the analytical framework of this dissertation to assess fertility outcomes under alternate regional conditions.
3. Theoretical Framework

3.1 Overview

The research question this dissertation addresses is whether a woman's fertility would change if 1) the type of family planning (FP) method used; and 2) the prevalence of use were to vary under alternate social and environmental conditions. This chapter describes contextual effects through the lens of the burgeoning field of social epidemiology. It also reviews previous theoretical models used to assess fertility outcomes in Sub-Saharan Africa, and describes the counterfactual theoretical framework used to answer Specific Aim 1 of this dissertation. Finally, it discusses Coleman's Social Theory framework, which assesses the association of interest at both the societal and individual levels, to answer Specific Aim 2.

3.2 Ideal experiment

In an idealized experimental setting, balance of known an unknown confounders would be secured through randomization of participants to assignment condition (Fisher, 1932). The resulting estimates, then, would be an unbiased measure of the effect of the exposure on the outcomes of interest (Rubin, 1974). For this dissertation, we would be able to randomly allocate women to different regional contexts, and assess the independent effect of different contextual effects on family planning (FP) choices, and therefore on a woman's fertility and under-five mortality events. However, it is both unethical and unfeasible to randomly assign persons to one condition versus another when the allocation would require relocation from one region to another (Oakes, 2004; Rossi, 1997; Heckman et al., 1995). Yet lack of random assignment may introduce
confounding, where population-level covariates influence both exposure and outcome (Oakes et al., 2006). Therefore, the research question must be answered using observational data. Nonetheless, the experimental design framework must be maintained in order to estimate the independent effect of FP methods on fertility and under-five mortality (Maldonado et al., 2002). It is necessary to mimic the experimental set-up by creating exchangeability between observations located in different regional contexts (Imai et al., 2008).

### 3.3 Contextual effects

The research question of this dissertation places great emphasis on the regional context in which fertility decisions are made. Therefore, it must be stated within the theoretical and methodological boundaries of a discipline that has society as its unit of analysis and health as its outcome. That discipline is social epidemiology, a branch of epidemiology that considers how social interactions and collective human activities affect health (Oakes et al., 2006).

The lens of social epidemiology can be useful to frame the issue of contextual effects. Indeed, it is a variation on the "problem of the commons". In its classic version, the problem arises when each shepherd allows his sheep to overgraze on the common land. Soon the land is barren, and all shepherds lose their herding grounds (Hardin, 1968). This situation illustrates how individuals seeking their own self-interest can yield a collective outcome that is advantageous to none (Oakes et al., 2006). For this dissertation, the "problem of the commons" is re-written: the social context in which each woman lives encourages her to have as many children as possible to increase her family's status in
society and guarantee support for herself in old age. Soon local resources are stretched beyond capacity, and the nation's infrastructure cannot heal, educate, or employ all its citizens.

The dissertation addresses this collective action problem by considering how unique regional characteristics combine to create contextual effects, which in turn determine differential access to contraceptive resources and fertility outcomes. However, we must use multi-level theoretical frameworks if we want to quantify the influence of population-level factors on individual-level associations (Oakes et al., 2006; Greenland et al., 2001). Therefore, in order to be useful to the research question at hand, the theoretical framework of this dissertation must account for: a) individual change in both the exposure and the outcomes; b) population-level factors that capture interactions between individuals, and c) the resulting changes in population-level parameters (Oakes et al., 2006; Oakes, 2004).

3.4 Previous theoretical models

Many of the theoretical models used in fertility studies employ population parameters to define the context where the association of interest develops. Most of the Demography and Epidemiology literature dedicated to explaining fertility patterns in Sub-Saharan Africa can be classified in one of three models: a) the reproductive behavior model; b) the socio-economic model; and c) the institutional model. The first one explains contraceptive use in relation to individual factors. The latter two draw on population-level factors to explain overall trends in FP use. Changes in these factors are
hypothesized to influence changes in the population's fertility and under-five mortality trends (Ezeh et al., 2009).

**Reproductive behavior model:** Changes in an individual's fertility preferences and behaviors explain changes in fertility. Empirical evidence suggests that fertility declines in most Sub-Saharan African countries are either preceded or followed by significant increases in contraceptive prevalence, as well as decreases in desired family size (Bongaarts, 2006, 2008; Garenne, 2007; Shapiro et al., 2008). To measure changes in fertility given an individual's preferences and behaviors, this model includes measures of: contraceptive use, desired family size, adolescent childbearing, and attitudes towards FP. This model also states that changes in individual factors are influenced by socio-economic and socio-cultural elements within the community, as well as the availability of healthcare infrastructures focusing on FP (Garenne, 2008).

**Socio-economic model:** Fertility is believed to be an economically rational response (Caldwell, 1982; Stecklov, 1999). In this model, the benefits of having children (i.e., additional workforce, security in old age) are weighted against the costs associated with child rearing (i.e., school fees, further subdivision of scarce resources). Environmental changes in contraceptive availability differentially impact different subgroups of women, according to the socio-economic characteristics of each group (Ezeh et al., 2001; Bongaarts, 2002, 2006, 2008; Schoumaker, 2004; Garenne, 2007; Shapiro et al., 2008). The cost-benefit analysis of fertility is re-evaluated on the basis of these changes, leading to different behavioral outcomes and differential contributions to the fertility trend. To measure changes in fertility given a group's socio-economic status, this model includes
measures of: women's educational attainment, female participation in the labor force, household wealth, cultural norms (usually measured by religion and ethnicity), and social development (measured by region and level of urbanization).

**Institutional model:** fertility trends change depending on the focus placed on FP by national and international organizations. Analyses of Sub-Saharan Africa health resources report that donor assistance for FP was considerably reduced to invest more heavily in HIV/AIDS programs (Van Delen et al., 2008; Cleland, 2009). This shift in donors' attention started in the early 1990s. Fertility has been stalling in Sub-Saharan Africa since then. This model proposes that dwindling FP resources in the public sector create differential access to FP services. Nationally, 64.6% of current FP users report obtaining contraceptives from the public sector (i.e., government dispensaries and health centers). Remaining users employ religious and private infrastructures (NBS, 2011). As the price of contraceptives increases due to limited supply, fewer of these current users can afford them (Davanzo et al., 1998). Consequently, fertility increases among the majority of women who cannot afford contraceptives any longer. To measure change in fertility given the public sector's role as a contraceptive provider, this model includes a measure of the proportion of modern contraceptive users who obtained their last method from a public facility.

Ezeh et al. (2009) draw their analytical framework from these three models. They suggest that changes in the FP services and education women receive from national and international organizations – coupled with changes in the community's socio-economic characteristics – are the contextual factors that influence a woman's preference in type
and frequency of FP method use. Changes in fertility trends, they argue, are a direct result of these individual reactions to the social and economic environment in which women live.

However, the frameworks cited in the Ezeh paper do not seek to create exchangeability across observations in their sample – that is, to mimic random allocation by making the exposed and non-exposed groups identical on all factors except the intervention condition. Rather, the frameworks consider different potential exposures and measure fertility changes over time. There is no attempt to estimate the independent effect of FP methods on fertility or under-five mortality events. This dissertation, instead, aims to estimate this independent effect for various contraceptive methods (Specific Aim 1). Therefore, we require a different framework to guide our analysis process.

Furthermore, the theoretical frameworks used to date consider only the pathways that lead from contextual factors to individual choices. There is no mention of pathways that explain how individual reproductive choices influence the regional context in which these women live (Specific Aim 2). Yet it is the sum of individual knowledge, attitude, and practices around contraceptive use that creates the social context in which reproductive decisions are made. Therefore, we use a different analytic framework – one that explains the influence of social factors on individual decisions, as well as the impact of personal choices on the social context.

3.5 Specific Aim 1: Counterfactual causal framework

The goal of epidemiological inquiry is to establish a causal link between a given biological mechanism or pathway and a specific disease (Beya et al., 1999; Macintyre et
al., 2000; Hernán, 2004). However, the causal pathway is seldom linear, and numerous external factors – individual, social, and environmental – can confound the association of interest. It is necessary to set up an experimental design that allows researchers to isolate the independent effect of the exposure on the disease outcome. The counterfactual causal framework is favored in many scientific disciplines for this purpose (Rubin, 1976, 1991; Sobel, 1995; Kaufman et al., 2000; Pearl, 2000; Maldonado et al., 2002; Shadish et al., 2002). It defines causal estimates as "comparisons of the potential outcomes that would have been observed under different exposures and units to treatment" (Little et al., 2000). The counterfactual framework allows us to ask whether differential regional effects influence a woman's reproductive options, and therefore her fertility outcomes, to different degrees – all other things being equal. Ideally, we would be able to randomly assign women to different regions and measure any differences in fertility and under-five mortality events that are due to different FP preferences.

However, the counterfactual model requires that different conditions be tested at the same time with the same sample, so that only the exposure varies (Hernán, 2004). Furthermore, as mentioned above, it is both unethical and unfeasible to relocate women based on random assignment to condition. Therefore, we must rely on an observational design. Specifically, the research question of Specific Aim 1 is recast to ask whether hypothetically changing social contexts affects a woman's contraceptive choices, and therefore her reproductive outcomes (Oakes, 2004). In this phantomatic intervention, we assign all women within a region to the same condition arm (i.e., exposed or non-exposed to a specific FP method). In other words, we assume that the regional context perfectly
predicts a woman's selection of a contraceptive method. The regional context is now the exposure to be administered. Then we can compare exposed and non-exposed regions to assess which FP method is most successful in reducing the region's fertility and under-five mortality rates.

3.6 Specific Aim 2: Coleman's Social Theory framework

Specific Aim 2 re-calculates the population projections of Tanzania from 2010 to 2025 under different contraceptive scenarios. This objective requires the use of hierarchical models, where individual changes in FP methods and prevalence result in changes in a woman's predicted fertility and under-five mortality events. From there, it is possible to estimate different population's growth trajectory given different individual-level parameters. The theoretical framework on this Specific Aim should incorporate a multi-level design to include both individual- and population-level measures of change.

James Coleman's 1990 Social Theory framework (also known as the "bathtub" for its trapezoidal shape) is especially well suited to accommodate the multi-level design that connects individual and population measures. The framework is composed of two levels. The "macro" level describes the social context and the environment in which individual actions take place (Coleman, 1990). For this dissertation, the macro level is the Tanzanian population at different points in time. We measure any changes in its size that occur between 2010 and 2025. The "micro" level, instead, describes the individual contraceptive choices of women in the community, as influenced by the larger social context (Coleman, 1990). For this dissertation, the micro level is composed of
respondents' FP choices, fertility patterns (as determined by their age and region of residence) and the number of under-five events experienced.

Specific Aim 2 is principally interested in the changes in size that occur at the population level. Therefore, it would be reasonable to only consider the macro level of the analytic framework. However, social change is grounded in the activities of constituents. Changes in overall reproduction trends can only be explained by assessing the association between FP use and fertility or under-five mortality at the individual level (Coleman, 1990). Therefore, we must examine the associations of interest at a lower analytical level, using measures collected from individuals. Then we can estimate changes in population-level fertility given the interaction of individual choices with regional conditions.

As seen in Figure 3.1, the "bathtub" is composed of three transition stages running between the two levels: a) macro-to-micro; b) micro-to-micro; and c) micro-to-macro.

a. At the "macro-to-micro" level, the size of the population in 2010 determines the number of women currently using a contraception method. When we vary the proportion of women currently using an FP method – from the current percentage up to an increase of 19% – we create different FP scenarios in which individual reproductive choices can develop.

b. At the "micro-to-micro" level, women may select one of the contraceptive options available – or choose to forgo FP methods entirely. At this level, individual reproductive choices have are directly associated to individual reproductive outcomes and under-five mortality events.
c. At the "micro-to-macro" level, the interaction of multiple individual reproductive outcomes, affected by different contraceptive types and prevalence of use, combine to create different population projections for 2025 depending on the FP scenario selected.
Figure 3.1 Representation of Coleman's "bathtub" for Specific Aim 2

SOCIETY

INDIVIDUAL
3.7 Summary

In summary, the counterfactual causal framework and Coleman's Social Theory framework seem to be the analytic models best suited answer Specific Aims 1 and 2, respectively. The first framework uses the counterfactual model to estimate the independent effect of each FP method on fertility and under-five mortality events, after hypothetically assigning regions – and all the women residing there – to the exposed or non-exposed condition. The second framework uses a hierarchical model to assess the individual-level association between each FP method and fertility or under-five mortality events. Then, it allows us to reconstruct population projections under different scenarios of FP type and prevalence.
4. Data Sources and Measures

4.1 Overview

The research question this dissertation addresses is whether a woman's fertility would change if 1) the type of family planning (FP) method used; and 2) the prevalence of use were to vary under alternate social and environmental conditions. In a clinical setting, it would be possible to randomize users of various FP methods to different fundamental risk factors of high fertility and high under-five mortality, and then to measure their differences in means on the outcomes of interest (Maldonado et al., 2002). However, ethical and logistical considerations forbid such a study. Therefore, this study uses an observational design, where participants are not randomly allocated to condition. Rather, their health characteristics and interactions with the environment are measured to assess associations with the exposures of interest. We use data from two primary sources to address the specific aims of this research: 1) the Tanzania Demographic and Heath Surveys (NBS, 2011); and 2) region-specific population projections (NBS, 2002a). This chapter describes each of the data sources, the information they offer, their strengths and limitations, and the major issues they present. Use of these data for secondary analysis purposes was approved by the Institutional Review Board of the University of Minnesota (study number: 1004E80754).

4.2 Demographic and Health Surveys

The Demographic and Health Surveys (DHS) is a database funded by the United States Agency for International Development (USAID). It collects data from 75 countries, including Tanzania, every two or three years since 1991. It gathers health
information (e.g., fertility, mortality, birth histories, childhood diseases, malaria, FP use, HIV/AIDS) on individuals (male and female), households, and children (five years or younger) (DHS, 2008). Datasets are available online for free download (DHS, 2010). The DHS is the most comprehensive data collection project for reproductive health information in developing countries, and as such is a prime source of reliable health information. It collects information on FP uses and perceptions, as well as fertility and mortality trends (NBS, 2011). It adheres to high standard of survey execution and employs standardized instruments (NBS, 2011; Cleland et al., 2006). Also, it consistently codes variables across years and countries, facilitating longitudinal and cross-country comparisons. Most importantly, it consists of microdata: person-level records that have not been aggregated to form summary statistics. Users obtain the full range of responses for individuals and can customize their tables and multivariate analyses according to their specific research question (MPC, 2010). Social scientists use these data to assess the effect of behavioral interventions, infrastructure improvements, and policy decisions on FP use (Sedgh et al., 2007; Richey, 2004; Prata et al., 2004; Khan et al., 2006; Chapman et al., 2010; Jato et al., 1999; Ali et al., 2004; Rogers et al., 1999; Hotchkiss et al., 2006). Also, DHS data are used to assess population growth trends (Prata, 2009; Ezeh et al., 2009; Masanja et al., 2008; Miller, 2010), and compare health indicators across time and countries (Prata, 2009; Ezeh et al., 2009; Cleland et al., 2006; RamaRao et al., 2003).

This study employs the 2010 iteration of the women's survey because it is the most recent survey to date that collects information on FP. Respondents are women ages 15 to 49 who are either permanent residents of the household or visitors present at the time of
the interview. This datasets include information on FP perceptions, use, consequences, and future intentions. Also, the DHS collects information on fertility and childhood mortality within the household, as well as dwelling characteristics, educational attainment, and employment status.

The Tanzania DHS dataset used in this study has some limitations. First, the smallest geographical identifier available is the region. Unfortunately, this is one of the coarsest geographical demarcations within the country. There are 26 regions in Tanzania, with populations ranging between 190,000 and 2,904,720 persons (NBS, 2002a). They house very different ethnic groups. Tribes in one region can be profoundly different in genetic make-up, culture, language, employment options, and infrastructure availability (Lawrence, 2009). Therefore, we cannot assume homogeneity at the regional level. While this lack of detail is less than ideal, coarse geographical units allow us to assess the associations of interest in different contexts (Ezeh et al., 2009). First, the presence of regional units makes the dataset hierarchical, where persons are nested within regions. Therefore, measurements can be estimated for both individuals and the regions in which they live (Oakes, 2004). Second, regional estimates take into account local determinants of FP use that would be lost in a country-level analysis. Finally, region-specific measures allow researchers to disentangle the independent effect of the economic and social environments on health (i.e., FP use, fertility) from that of the individual or her household (Oakes et al., 2003; Oakes, 2004; Sampson et al., 2002).

Second, the most recent FP data were collected in 2010. The DHS conducts a survey every two or three years in each country (the most recent of which is ongoing), but does
not collect information on all topics in order to avoid lengthy interviews. Therefore, this study employs data that are at least two years old. However, FP use, fertility, and under-five mortality trends are slow to change across years. Indeed, Tanzania's total fertility rate increased by 0.7% per year between 1991 and 2004, resulting in a stall in population decline (Ezeh et al., 2009). There are no indications that population trends have markedly changed since 2010. Therefore, the results of this study can still be considered applicable to today's population growth trends in Tanzania, despite the date of data collection.

Despite these two limitations, the 2010 DHS dataset is the most appropriate source of data to answer the research question. It provides:

- the most comprehensive collection of reproductive health information from Tanzania
- high standards of survey development and data collection
- microdata records for customized analyses
- region-level detail to estimate the independent effect of the context on health characteristics
- free online download with minimal administrative roadblocks

4.3 Region-specific population projections

In 2002, the Tanzania's National Bureau of Statistics (NBS) released population projections for each region of the country. The projection period runs from 2002 to 2025. Projections are stratified by year, gender, and urban/rural status within region. Each document reports projection estimates for both single- and five-year age ranges.
NBS used the 2002 Population and Housing Census mid-year population estimate as the base population for the projection, stratified by age and sex. The population projection software used for this projection is Demographic Projection (also known as DemProj), a computer program for making population projections for countries or regions. The following inputs were used to obtain the base population:

- Reported population distributed by five year age-groups and sex
- Sex ratio at birth (defined as male births per 100 female births), is assumed to be 103
- Mortality data at two points in time: 1988 and 2002
- Age-specific fertility rates (ASFR) from the 1991/92 and 2004/05 DHS surveys. DHS data were selected because they provide more reliable fertility information compared to the Census. Also, DHS fertility data is based on birth history of individual women.

Once this information was collected, NBS statisticians estimated the population for a desired future point in time using population growth rates, which are based on the fertility values calculated prior. This step estimates the region-specific adjusted population estimates, disaggregated by single- and five-year age ranges, sex, and urban/rural status (NBS, 2002b). The information is not released in tabular form, but rather must be abstracted from the region-specific files published on the NBS' website and available for free download.

We sum estimates across regions to obtain age- and sex-specific population projections for each year for the entire country. Because we employ 2010 DHS data to
calculate all measures of fertility and under-five mortality, we use NBS projections estimates from 2010 onwards. Data from 2010 and 2015 allow us to calculate future survival rates for each age group. We use these rates to estimate population projections for each five-year interval, as recommended in most projection methods (Preston et al., 2001). The population born into each year's 0-5 age group is adjusted for different proportions of FP method's use. The goal is to obtain population projections adjusted for different proportions of FP use among reproductive age women. Under-five mortality is already taken into account in the survival rate calculated from the 2010 and 2015 data. No additional information on contraceptives' effect on under-five mortality is considered at this point, since its effect would be negligible when re-estimating Tanzania's population projections.

The NBS population projection documentation has some limitations. First, data are released at the regional level. The only additional geographical differentiation within regions is a person's urban/rural status. However, the DHS releases data at the region level as well. Therefore, geographical comparisons between the two datasets are easily done. Second, the projections do not specify the number of persons in each age group who died from one year to the next. However, simple demographic strategies allow users to estimate the survival rate in each age group. Thus, the number of under-five deaths in each year can be imputed easily.

Despite these limitations, the NBS' region-specific population projections are the most appropriate sources of data to answer the research question. They provide:

- records for the entire Tanzanian population, thus avoiding undercount issues
- de facto enumeration to capture information from both residents and visitors
- region-level detail to match population estimates calculated from the 2010 DHS dataset
- free online download with minimal administrative roadblocks

4.4 Sample representativeness

The NBS population projection data have no issues with representativeness. By definition, the Census collects information from the entire population residing in the country on the day of the enumeration. Therefore, population projections drawn from Census data are valid for the entire population of Tanzania.

The DHS dataset is not as straightforward. Respondents are a representative probability sample of the Tanzanian population. They are enrolled in the survey through a two-step selection process. First, 475 clusters are selected from a list of enumeration areas from the 2002 Census. Second, DHS surveyors conduct a complete household listing exercise within all the selected clusters. Households are then systematically selected for participation in the survey (NBS, 2011). The sample is selected with unequal probability to expand the number of cases available for certain areas. We apply individual weights to obtain the proper sample size for descriptive statistics. We do not employ weights when estimating regression or correlation coefficients because otherwise the sampling variances and confidence intervals would be overestimated in oversampled areas (Rutstein et al., 2006).
4.5 Unmeasured confounding

The 2010 DHS dataset does not release information on a respondent's ethnicity or religious affiliation. These variables would be of interest to the study. In Tanzania, ethnicity divisions are not based on race (which is overwhelmingly Black), but rather on tribe of origin. Religion is often a determinant of women's fertility preferences and opinions on contraceptive methods. These variables can act as proxies for distinct cultural beliefs and attitudes towards high parity. Their inclusion in the analytical framework would have allowed us to better define the social context in which FP decisions are made (Eckersley et al., 2001). Without this information, cultural preferences and practices stemming from specific ethnicities remain as unmeasured confounders of the associations of interest. Adjustment for cultural attitudes must rely on a respondent's region of residence. This indicator can capture some of the social factors that influence FP use, and consequently high parity.

4.6 Missing values

The DHS includes some missing data. First, the enumeration was de facto – so women away from their household at the time of the interview were not included in the sampling frame.

Second, the questionnaire includes health questions of a sensitive nature (i.e., contraceptive use, fertility, HIV/AIDS status, sexual activity). Previous studies suggest that a lack of privacy when answering questions on FP and other sensitive topics results in social desirability bias, where women do not report their true FP behaviors and opinions in order to give socially acceptable answers (Plummer et al., 2006; Nnko et al.,
Survey administrators are instructed to conduct the interview in private (NBS, 2011). However, privacy may be difficult to obtain if the dwelling is small and the circle of visiting friends and family is quite large. Therefore, DHS data may underestimate the variety of FP methods considered and used. According to the 2004 DHS, 69.5% of interviews were privately held. However, there is no privacy information for the remaining interviews (DHS, 2008). Also, interviewers read a comprehensive list of all contraceptive methods – both modern and traditional – to improve recall. This way, the risk that participants omit or forget one or more methods is minimized.

Third, the DHS dataset likely underestimates neonatal deaths. Enumerators for both the census and the DHS are instructed not to count stillbirths. However, it is difficult to assess whether a child was born dead or died soon after, especially when many births occur outside healthcare facilities without assistance from trained health personnel (Justesen et al, 2000; Setel et al, 2007). Also, many women avoid mentioning neonatal deaths, since the child was not considered human yet and therefore was not mourned (Haws et al, 2010; Kidolezi et al, 2009). These events lead to an undercount of the number of children dead. Consequently, the under-five mortality rate of each region may be underestimated as well.

4.7 Summary

In summary, two different data sources are used to answer the research question: the 2010 iteration of the Demographic and Health Surveys and the 2002 region-specific population projection estimates calculated by the Tanzanian National Bureau of Statistics. The 2010 DHS represents the gold standard for data collection practices on FP
use, fertility and under-five mortality. The NBS population projections, instead, represent the baseline information from which all FP-specific adjustments to population size can be made. This study benefits from the strength of these data, their research-based measures, and the variety of individual-, household-, and region-level factors that help contextualize the association between FP and population growth trends.
5. Validation of DHS items

5.1 Overview

The Demographic and Health Surveys (DHS) is one of the most widely used datasets to measure health outcomes in developing countries. It is often used to design fertility reduction interventions in sub-Saharan Africa. However, fertility trends in most of the continent remain at a standstill. One reason for this lack of success may be the presence of unknown bias in the data. Few qualitative studies have been conducted to assess this possibility. It is best to consult Tanzanian women to assess whether DHS items are interpreted as intended, and whether there are any conditions that would bias answers. This chapter describes the qualitative sub-study we conducted in July and August, 2010 in Tanzania among village women. It reports the recruitment protocol, the DHS items submitted for validation, and the themes that emerged from the focus groups. Finally, it places the findings within the broader context of the dissertation.

5.2 Background

One of the key sources of data used in previous fertility studies – and this dissertation – is the Demographic and Health Surveys (DHS), a USAID-funded database administered in 75 developing countries. The DHS data inform the design of numerous interventions, as well as cross-sectional, prospective, and cross-country observational studies (Sedgh et al., 2007; Richey, 2004; Prata et al., 2004; Khan et al., 2006; Chapman et al., 2010; Ali et al., 2004; Jato et al., 1999; Rogers et al., 1999; Hotchkiss et al., 2006).

However, efforts in contraceptive promotion are failing to make a significant impact on women's reproductive outcomes in many Sub-Saharan African countries. Fertility
rates have remained stagnant since the early 1990s. In some, falling population trends have started to reverse (Ezeh et al., 2009). One possible explanation is that the DHS data used in these studies incorporate unknown biases that are specific to the culture and social structure of the region. These biases may infiltrate in the preliminary work on family planning (FP) promotion, and lead to ineffective interventions. Biases may originate from the DHS’ standardized mechanism of data collection, which forces questionnaire items to be comparable across countries. A standardized questionnaire may not be able to accurately capture local customs and preferences. If these biases are not taken into consideration, analyses may produce poor estimates of contraceptive use. Qualitative validation studies are routinely performed by the DHS on portions of its questionnaires (Yoder et al., 2004). However, to date none has been conducted on the FP items used in Tanzania. It is best to consult the women themselves – in a less formal, more relaxed way – to assess whether the DHS items on FP in Tanzania are understood and answered as intended.

The research question this qualitative sub-study addressed is whether there are unknown biases in the Tanzania DHS contraception items (DHS, 2008). Specifically, we assess respondents’ comprehension of DHS items and whether they reported any social desirability bias in their answers. Results from this sub-study assess the validity of the DHS items that deal with FP, and inform the analysis portion of the dissertation.
5.3 Methods

5.3.1 Study design

We conducted seven focus groups in the districts of Karatu and Arusha, in the Arusha region of northern Tanzania. The focus groups took place in July and August 2010. We interviewed between six and eight women per group. The target population was composed of village women age 15 or older. We collected data in collaboration with two non-profit organizations (NGO) operating in Tanzania: Savannas Forever Tanzania and WellShare International. Funding was provided by the Hawley Award from the Division of Epidemiology and Community Health at the University of Minnesota and the Developing Global Scientists and Engineers (DGSE) program "Collaborative Technology Innovation for Public Health Improvements in Tanzania", funded by the National Science Foundation. This study and all related materials were approved by the Institutional Review Board of the University of Minnesota (study number: 1003P78822).

5.3.2 Target population

We chose village women to be the target population of this sub-study because they comprise 80% of the female population in Tanzania (Sullivan et al., 2006). Also, the social context in which they live places greater constraints on FP choices for women, compared to men (Feyestan et al., 2000; Sullivan et al., 2006). Women have a duty to give their family as many children as possible, and have fewer resources and opportunities to use contraceptives. Therefore, village women are exposed to more social and environmental pressures that shape reproductive choices, compared to men.
We chose rural villages over urban settings because environmental constraints of contraceptive availability are greater, compared to urban areas. Indeed, villages offer fewer healthcare resources and a very limited range of contraceptive options. Also, the social constraints of contraceptive use are greater compared to urban areas. Rural areas maintain stronger conservative values, so high parity is more highly prized in villages than in cities. Finally, village dynamics influence use and non-use of each FP strategy. In urban areas, different influences on FP use would affect participants to various degrees. It would be impossible to isolate specific determinants of FP use that affect the entire community. In a village, influences are fewer, easier to identify, and can potentially affect all women to the same degree (Sedgh et al., 2007).

5.3.3 Recruitment

The two NGOs, WellShare International and Savannas Forever Tanzania, selected the villages for the focus groups to simplify transportation and bureaucracy issues. Staff members from each NGO applied to local government officials to enter the villages for research purposes. Upon receiving government permission, staff members met with the village leaders and agreed upon a recruitment protocol for both their projects and this study. The NGO's projects consisted of training courses on micro-financing, distribution of record-keeping books to traditional birth attendants, and baking classes. Topics and materials did not touch on FP education or contraceptive use training.

This protocol required that village leaders in each community invite potential participants to join in the NGOs’ projects. Women were informed that they would participate in various activities with a group of their peers. Selected women gave their
verbal agreement to participate in the session, and were free to retract at any time. We did
not attempt to recruit additional women in order to respect the leaders' role as decision-
makers in their communities. Once women agreed to participate in the NGOs' project,
they were automatically eligible to join the focus group for this sub-study.

5.3.4 Focus groups

Participating women were asked to give oral consent to join the focus group for this
sub-study. The consent form was approved by the Institutional Review Board of the
University of Minnesota, translated from English to Swahili by university-educated local
staff members, and read to participants in Swahili. English and Swahili copies of this
form were sent to the National Institute for Medical Research, Tanzania's ethical board
for health-related research.

The focus groups were led in Swahili by a trained moderator – a native speaker with
experience leading focus groups on health topics in village settings. After describing the
proceedings of a focus group, the moderator posed the questions. She ensured that all
participants had a chance to give their point of view, prodded for answers if some
members were reticent, and encouraged differing opinions. During each focus group, we
took notes of the surrounding conditions and events, so to put findings in the context of
the village where they were collected. Our presence in the group was acknowledged, but
did not create noticeable distractions or reticence among participants.

Each focus group lasted between 45 minutes and one hour. All conversations were
recorded using a digital voice recorder. At the end of each session, the moderator invited
participants to give comments, amendments or corrections, as well as add any comments
that were not mentioned before. Participants were compensated with one piece of soap each (a common practice for projects in this region). There were no follow-up sessions.

5.3.5 Questions

The moderator introduced the DHS items by setting the scene of a standard DHS interview. She described the situation as if it were a narrative, and the respondents were the actors. The scenario was constructed based on the training materials given to DHS interviewers before they leave for the field (DHS, 2006). It reports the selection and consent procedures followed by DHS interviewers, and describes the setting in which the interview takes place. The scenario read:

Your local leader told you that your house has been selected to participate in a survey. On the appointed day, a woman you never met but who is from your region and speaks Swahili arrives to your house. She says she is conducting a national survey on behalf of a local organization. She asks if you would be interested in participating in this survey, where she will ask you about various health issues. The information you give will help the government to plan health services. She assures you that you can refuse to participate or drop out at any time. If you say yes, she will ask you all her questions in private, where none of your friends or family members can hear your answers, and none of your answers will be reported to anyone you know. The interview will take between 30 and 60 minutes.

After reading this scenario, the moderator told participants that they would be asked some questions on contraceptives, and that they should answer as if they were in the situation described. She then proceeded to ask the DHS questions selected for validation. The items were:

1. Which ways or methods have you heard about? [oral contraceptives, intra-uterine devices, Depo Provera, diaphragm, male condoms, female condoms, female sterilization, male sterilization, foam or jelly, rhythm, withdrawal, implant, lactational amenorrhea, abstinence, emergency contraception, other]
2. Have you ever used [method]?

3. What is your main reason not to use [method]?

4. Do you think you will use a contraceptive method to delay or avoid pregnancy at any time in the future?

5. At the time you became pregnant with your last child, did you want to become pregnant then, did you want to wait until later, or did you not want to have any (more) children at all?

These items capture current and future trends of FP strategies in Tanzania, but they may incorporate challenges with comprehension. Comprehension is defined as a process that requires respondents to: attend to the question and its instructions, assign a meaning to the surface form of the question, and infer the question's point (Groves et al., 2009). Therefore, to interpret a question correctly, the respondent must be able to determine the set of permissible answers (Groves et al., 2009). However, the first three items assume that respondents have some knowledge of pregnancy prevention methods. In rural villages, where healthcare services are few and high parity is greatly valued, this assumption may not be supported. Interviewers would need to give respondents additional background information of FP. The fourth item requires judgment to report on future, hypothetical fertility behaviors. The time frame is not well defined, so answers may include both immediate possibilities and future intentions. This judgment may be complicated by Tanzania-specific social pressures, environmental constrains, and personal preferences that determine contraceptive use. Some of these factors are liable to change in the future. Answers would have to take into consideration these variations as
well. Finally, the latter item is quite long-worded and includes three different options. It may be difficult for respondents to parse out each element while assigning meaning to the complete question. The issue may be compounded by the item's heavy demand on memory. It may be difficult for older women to remember the motivations behind their last pregnancy, especially if it occurred years prior. The combination of item length and recall make this a difficult question to answer thoroughly. In light of these concerns, the moderator assessed the respondents' comprehension by asking:

- What do you think this question is asking?
- Would you answer this question? If yes, how would you answer?

These items also were selected because they may be subjected to social desirability bias. This bias occurs when a participant is reluctant to admit contraceptive use because of the attitudes, beliefs and perceptions in her community (Gordis, 2004). The DHS interview scenario explicitly says that questions should be asked in private. However, private interviews are difficult to implement in villages: dwellings are often small and house many relatives and visitors. Outside areas can be even more crowded and offer no expectation of privacy. Further, contraceptive use is a sensitive issue under any circumstance, given the social pressures against it. It is difficult to imagine that this would be an easy topic of conversation to breach with a stranger. Therefore, to assess social desirability bias, the moderator asked participants:

- Why would you answer this way?
- Would you change your answer if conditions were different? How?
5.3.6 Analysis

At the end of the data collection period, conversations were transcribed, translated from Swahili to English, and encrypted. All transcripts were stripped of participants' names and other identifiers. First, we reviewed all translated transcripts and field notes by village. We highlighted any portion of the conversation that concerned the DHS items: whether they were immediately understood, the reactions they evoked, and how the question was answered (e.g., in full, partially, hesitantly). Second, we compared these fragments across villages to identify common themes. If there were differences between villages, we created village sub-groups according to the village's degree of similarity in themes. Also, we looked for other characteristics that made the villages within a sub-group more similar to one another than to the rest of the villages. Third, we used information from the rest of the transcript and notes to contextualize each emerging theme.

5.4 Results

5.4.1 Participants

We conducted one focus group in each of the seven villages visited: five in the Karatu district (Kambi ya Simba, Chemchem, Makhoromba, Jobaj, and Upper Kitete) and two in the Arusha district (Mzimuni and Oldonyowasi). The conversation was usually held outdoors near the village clinic or a government building to show participants that the focus group had the approval of the local authorities.

In total, 53 women were interviewed. Each group was composed of six to eight participants, age 15 or older. The average age was 35, and the average number of children
per woman was 5 (with a minimum of 0 and a maximum of 13). Approximately 62% of participants were married. All were residents of the village in which the focus group took place. Their knowledge of Swahili was excellent, indicating that all had completed at least some part of primary education.

5.4.2 Village characteristics

- **Kambi ya Simba, Mzimuni, and Upper Kitete**: The villages are located approximately one hour from the district cities of Karatu or Arusha. They can be easily reached via a combination of paved and well-kept dirt roads. Arusha is one of the largest urban centers in the country, houses numerous international organizations, and is close to the Kilimanjaro International Airport. Karatu is a necessary stop for tourists traveling to the Serengeti National Park. Therefore, high-end services and products trickle into the villages on a regular basis. These communities have clinics and medical shops either on their premises or very close by (less than one kilometer). Each village also houses a number of small independent businesses. Mobile clinics (i.e., vans that carry trained healthcare staff, medical equipment, and surgery instruments from the cities, and are sponsored by local NGOs) visit the villages on a regular basis because of their proximity to the urban centers.

- **Chemchem and Jobaj**: These villages are located in rural areas of the country, but are connected to district cities via well-kept dirt roads. Travel time from main urban centers varies between half an hour and two hours by car. Inhabitants divide themselves between pastoralists (with cattle and chickens) and cash crop agriculturalists. Each village has its own clinic, which is staffed with local medical personnel. Mobile clinics come at a
regular interval to provide surgeries and medications that cannot be stocked in the village. Also, they provide some health education if there is time after visiting all the patients (a rare occurrence). The villages receive medical supplies from the government once every month. Because connections with the urban centers are reliable, there is periodical communication about health resources needed. Therefore, there is a good chance that specific requests will be satisfied.

- **Makhoromba and Oldonyowasi**: These are very rural villages. It can take between one and five hours to reach the nearest urban center by car, depending on road and meteorological conditions. Most inhabitants are agriculturalists who tend to small kitchen gardens. Neither village has a clinic or a medical shop within a five kilometer radius. Mobile clinics come seldom. They are scheduled to visit the villages approximately once every month, but the interval between visits can be highly variable. The villages receive medical supplies from the government once every three months, but re-stocking does not always meet current needs. Rather, there are a few items that are included in each delivery, but it is difficult to request – and receive – alternative medications because of communication difficulties with the supply authorities.

### 5.4.3 Focus group settings

Participants were willing to address the topic of FP in a group of peers. The fact that the focus group received the approval of the local authorities before starting gave legitimacy to the meeting. The moderator was a Tanzanian woman with experience in conducting focus groups on reproductive health in different settings. In both districts, she was perceived as trustworthy and unlikely to display condescending attitudes about
contraceptive use. In the Karatu district, she represented WellShare International. Given the NGO's excellent reputation in the area, she was not suspected of reporting sensitive information to others outside the group. In the Arusha district, she was seen as an outsider without motive to use the information collected against the participants.

The focus groups were held close to the clinic, but in secluded areas where there were fewer noises and distractions. Participants knew that their presence in the focus group would not be linked to their use of contraceptives because they were already engaged in other NGOs' projects. A number of persons passed next to the ongoing focus groups, but only a few women stopped to gather information. Their presence did not seem to concern any of the participants, and indeed there was no break in the flow of the conversation. Finally, only two women in two different villages left the focus group before its conclusion, and both told the moderator they were leaving to attend to other tasks. Neither mentioned embarrassment or invasion of privacy as the reason for leaving. Therefore, the setting where the seven focus groups took place was unlikely to create anxieties about breaches in privacy.

5.4.4 Comprehension of DHS items

Participants showed good comprehension of all DHS items. They addressed each question posed by the moderator, and gave complete answers. None asked for the items to be repeated or clarified. The moderator encouraged all participants to speak, often prodding the younger women who may be silent to avoid talking out of turn when their elders were present. By obtaining answers from all participants, the moderator was sure
that everyone had understood the question, and that the occasional silence was not due to incomprehension.

Respondents understood the DHS scenario read to them. The narrative had three purposes. First, it made it easier for listeners to remember the details and follow the instructions for validation (Yarkoni et al., 2008). Second, by recreating the setting of DHS interviews, respondents could contextualize the items and understand the purpose of these sensitive questions. Third, respondents answered the items under the same conditions as the DHS interviews. This allows the items to be validated under the original conditions.

The first three items were: 1) "Which ways or methods have you heard about?"; 2) "Have you ever used [method]?"; and 3) "What is your main reason not to use [method]?". The main concern was that respondents in rural villages would not know enough about pregnancy prevention methods in general to understand what was asked of them. However, participants were aware of at least one modern contraceptive method even in the most remote villages. Therefore, they were able to answer the questions completely. The item asking about used contraceptive methods caused some embarrassment among younger participants because it required them to report their FP strategies to the entire group. However, the moderator encouraged group members until the item received a full answer in each focus group.

In the more urban villages, women only used modern methods (i.e., injectable contraceptives, implants, male condoms, and oral contraceptives). Almost every participant agreed that modern methods were more effective than traditional ones.
Nonetheless, many participants disliked modern methods because of the side effects experienced or reportedly associated with them (e.g., cancer, nausea, irritations, weight loss). In semi-urban villages, participants use a variety of FP methods – both modern and traditional. However, there was little knowledge about methods available outside the village. Respondents reported the positive traits of modern methods (e.g., protection from HIV/AIDS, greater effectiveness in preventing pregnancies) along with their side effects. In rural villages, respondents only knew about oral contraceptives and periodical abstinence. Contraceptive education occurs only when the mobile clinic comes to the community. Because of their limited knowledge, respondents did not want to speculate on the advantages of one method over another.

The other two DHS items did not cause participants any problems either. The fourth item was: "Do you think you will use a contraceptive method to delay or avoid pregnancy at any time in the future?". The item's timeframe is poorly specified. Nonetheless, respondents in all focus groups interpreted the question to mean a more distant future. Most women said that they intend to use a contraceptive method in the future, if the proper education and availability conditions are met. In more urban villages, women said they want to continue to use modern methods (i.e., oral contraceptives, male condoms, and injectable contraceptive), but would like to have a greater variety of methods available. In semi-urban villages, women use a mix of modern methods (i.e., injectable contraceptives and implants) and traditional ones (i.e., period abstinence). To increase contraceptive use in their village, respondents wanted FP education to be dispensed to both men and women, so decisions can be made jointly. In rural villages, women mostly
use traditional methods. They would prefer to switch more effective, modern methods. However, they do not feel they can ask for a wider variety of contraceptive methods because they would not know how to use them. Future use of a contraceptive method is associated with future FP education.

The fifth item was: "At the time you became pregnant with your last child, did you want to become pregnant then, did you want to wait until later, or did you not want to have any (more) children at all?". The item is long-worded and imposes a heavy burden on memory. However, no participant was confused by the length of the question or the multitude of options. Each respondent remembered her last pregnancy in detail, and could recall whether it was desired or not. None of the respondents said that they became pregnant when instead they did not want any more children. Rather, about half of respondents said they became pregnant when instead they would have preferred to space the children farther apart. The other half said they planned their last pregnancy. Semi-urban villages reported the highest number of planned pregnancies. Urban and rural villages, instead, reported approximately the same number of planned and unplanned pregnancies. Therefore, a village's degree of urbanization did not seem to impact its number of planned pregnancies.

Overall, about half of respondents said they planned their last pregnancy. However, the social context in which they live favors high parity. Rather than desiring their latest pregnancy, many participants may have just fallen in line with social conventions. Available FP options would be seen as irrelevant then. Finally, all participants said they would prefer to space rather than limit their number of children. This indicates that
modern contraceptives – especially permanent and semi-permanent ones – are unlikely to take strong hold in this area.

5.4.5 Social desirability bias

In the second part of the focus group, participants explained if and how their answers would change under different conditions. They reported that they would honestly answer FP questions from the DHS survey only if they were guaranteed privacy and, in some cases, secrecy during the interview. The level of privacy necessary varied between respondents. Some said that they would not answer truthfully regardless of who was in the room, while others said that they would lie only if a man were present.

In the more urban villages, participants stated that conversations on FP strategies are important to a woman's health and her family's wellbeing, and should be dealt with openly. Therefore, their answers would remain the same under any circumstance. The women reported they feel comfortable discussing FP with the village healthcare staff and their female relatives. However, they would be reticent to discuss the topic in front of their fathers or other male relatives. In the semi-rural villages, participants said they would give truthful answers on their use of contraceptives only if they were in a private setting. The presence of any other person in the room during the interview would require them to change their response to more socially acceptable answers. Therefore, both the content and detail of answers would be compromised if privacy could not be guaranteed. In the rural villages, participants said they would fully and honestly answer all FP questions posed by the interviewer – but only if they were able to give their answers in a
private space. If the conversation were to take place in a more public setting, participants said they would give false information.

5.5 Discussion

We conducted seven focus groups on FP in seven villages in Northern Tanzania. Participants showed good comprehension of the DHS items, but said they would be hesitant to give truthful answers in the presence of men. The aim of this study was to assess comprehension of the DHS items on FP, as they are asked in a Tanzanian setting. Women seem to understand these questions well, thus suggesting that the language of the items is appropriate for the target population. Hypothetical questions also were answered in full. Hence, the items themselves do not seem to contain any bias that could be determined through qualitative data. This finding supports the validity of the DHS items as tools to assess FP use in Tanzania.

However, the conversations revealed a strong social desirability bias. Respondents would change their survey answers in a DHS interview if another person were present – if especially a male relative – because they perceived their FP behaviors to be inadmissible. The DHS training manual states that interviews must be conducted in private by a surveyor of the same gender as the interviewee. Whether this is always feasible, however, is doubtful. Therefore, social desirability bias may be present in DHS data.

The results of this qualitative study suggest that contraceptive use under-reporting is a concern in the DHS questionnaire. This possibility is worrisome for this dissertation because prevalence of contraceptive use is the exposure of interest. The degree of
missingness depends on the social constrains placed on FP use in each village, and the consequent need for privacy when admitting to contraceptive use. Therefore, the analytical plan includes a sensitivity analysis that repeats the analytic process of Specific Aim 1 – where we assess the independent effect of FP methods on total fertility rate and under-five mortality rate – using only answers from the sub-group who reportedly conducted the DHS interview in private. If results vary between the sample and the sub-sample, there is indication that social desirability bias may be present in the data. We will interpret the results of the dissertation in light of this possibility.

This sub-study has a number of limitations: a) during analysis, some of the data's richness was lost when information was coded into standard categories. We maintained all information that could be compared across villages, but not all unique situations were retained; b) data collection was time consuming, and we could only conduct one focus group per village. Hence, the sample size for this sub-study was only 53 women; c) social desirability bias could have been strengthened by discussing a controversial matter with peers; d) focus groups took place outdoors or in poor structures. Many distractions and interruptions would have been avoided in a more controlled setting; and e) our results cannot be generalized to other countries because of the specific cultural factors around FP use in Tanzania.

This sub-study also has several strengths: a) it identified potential biases in the DHS questionnaire; b) it targeted women living in rural villages, who are at higher risk of unmet need for FP than women living in cities; c) the close collaboration with NGOs allowed us to take advantage of a pre-existing research infrastructure; d) villages are
well-defined units with clear membership, where determinants of FP use can be better defined than in more dynamic areas; and e) the methodology employed here for the post-test survey evaluation of the DHS can be generalized to the evaluation of other large-scale datasets.

5.6 Summary

In conclusion, barriers to FP use produce stagnation in Tanzania's fertility rates – and consequently in the progress towards equitable distribution of resources. We designed a qualitative study that: a) takes place in rural villages, where the unmet need for FP is highest; b) identifies modifiable barriers to use at the individual, social, and environmental level from a potential user's point of view; and c) addresses potential biases in DHS questionnaire on FP use and perceptions.
6. Analytic Strategy

6.1 Overview

The research question this dissertation addresses is whether a woman's fertility would change if 1) the type of family planning (FP) method used; and 2) the prevalence of use varied under alternate social and environmental conditions. This chapter describes the exposure, outcome and covariate measures, as well as the steps taken to estimate their values. Also, it outlines the analytic strategy used to address each aim, as well as the sensitivity analysis done to assess the extent of under-reporting in FP use prevalence and under-five mortality rate. Finally, it discusses the main issues and proposed solutions, as well as the analytic models used to answer each question.

6.2 Hypothetical counterfactuals

As outlined in Section 3.2, we cannot randomly assign women to a specific FP method. We must rely instead on a hypothetical experiment to assess the effect of each FP method on the total fertility rate (TFR) and the under-five mortality rate. In Specific Aim 1, observations are hypothetically exposed or not exposed to a specific FP method. Given the hypothetical counterfactual, the exposure arm is composed of observations that are assigned to a specific FP method. The control arm, instead, is composed of observations that are not assigned to that specific FP method. Therefore, the control arm includes both contraceptive non-users and users of all other FP methods in the sample. In Specific Aim 2, we hypothetically increase the prevalence of a specific FP method to assess changed in the projected population size between 2010 and 2025. Given the hypothetical counterfactual, increasing the prevalence of one contraceptive method
implies a decrease in both the proportion of non-users and the proportion of users of other FP methods. For each FP comparison, the assumption is that all other FP methods have no effect on fertility and under-five mortality, and consequently on population size, when compared to the specific contraceptive under observation. They constitute the null control in this hypothetical experiment. Also, we assume that women in the control group are able to switch to any contraceptive method, regardless of their social and environmental characteristics.

6.3 Outcome measures

This study assesses the effect of different FP methods on two outcomes: fertility and under-five mortality. Fertility is directly affected by FP methods, since correct and consistent contraceptive use reduces the risk of pregnancy, thus limiting the number of births per woman. Under-five mortality is affected by FP methods because contraceptives can be used to space pregnancies farther apart. The more time there is between births, the higher the probability that a child will receive the necessary care and nutrition to survive past age five. Also, the under-five mortality rate is a common measure of a country's state of development, compared to other countries.

6.3.1 Fertility

The 2010 DHS reports the birth histories of up to 20 children per respondent. These records include the dates of birth and death of each child, as well as their age at the time of the interview. For the purpose of this study's research question, fertility is captured through two measures:
**Individual parity:** By appending each woman's birth records and then collapsing them by respondent ID, we create a dataset that reports the number of children born to each woman in the sample. Respondents are then divided into seven age groups of five years each (from ages 15-19 to ages 44-49), to account for differential fertility rates at different maternal ages. This way, we can tabulate births by maternal age group. The DHS recommends that the number of children be restricted to those born within the 36 months that preceded the interview. This subgroup is identified by subtracting the century month code (CMC) value of the child's birth date to that of the interview date. This strategy allows researchers to assign children to the maternal age group in which women found themselves at the time of birth. While the age groups are in five-year intervals, the DHS documentation describes this three-year period is a compromise between the need for recency and reduction of sampling variation (Rutstein et al., 2006). The individual-level measure of fertility, then, is a sum of the number of births reported by each woman that occurred in the 36 months preceding the DHS interview.

**Region's total fertility rate (TFR):** The DHS documentation defines total fertility rate as an age-period fertility rate for a cohort of women. It measures the average number of births a group of women would have by the time they reach age 50 if they were to give birth at the current age-specific fertility rates. The TFR is expressed as the average number of births per woman (DHS, 2010).

The DHS documentation describes the procedures to obtain TFR for the entire country (Rutstein et al., 2006). We modified the process to obtain region-specific values of TFR. This measure of fertility uses the individual-level measure of fertility described above as
its numerator (after stratifying it by the respondent's region of residence). The
denominator, instead, is the number of women-years of exposure. This value is the sum
of the number of months exposed in the five-year age group during the 36 months
preceding the interview, divided by 12. A woman can contribute to only two five-year
age groups during the 36-month period. This measure also is stratified by the
respondent's region of residence. To obtain the region's TFR value, first we calculate the
age-specific fertility rate (ASFR). This value is calculated as the quotient of the
numerator divided by the denominator for each age group, multiplied by 1,000. The result
is a region-specific average rate over the 36-month period, expressed as an annual rate.
Finally, the TFR is calculated as the sum of the ASFRs for all women within a region,
multiplied by five – so to cover the five-year period preceding the interview (Rutstein et
al., 2006).

The TFR is a valid measure of region-specific fertility rate only if maternal age is
assumed to be homogeneously distributed across regions. If this is not the case, the ASFR
is a more accurate measure of fertility. To test this assumption, we compare the age group
distribution across regions after adjusting for sample weights. Also, we contrast the DHS
age distribution with that calculated from the 2002 Census on the same target population:
women ages 15 to 49, divided into five-year age groups (IPUMS, 2010). Results suggest
that the age distribution is indeed homogeneous across regions. Therefore, no
stratification by age group is necessary, and TFR can be considered a valid measure of
region-specific fertility.
6.3.2 Under-five mortality

Under-five mortality also is captured through two measures:

**Individual under-five mortality prevalence**: using the same appended dataset that records the number of children born to each woman, it is possible to estimate the number of under-five deaths experienced by the respondent in the 60 months preceding the DHS interview. We chose this five-year cut-off point because it allows us to attribute each death to the maternal age group in which it occurred. Also, we consider only the most recent deaths – those that could be associated with current FP use – rather than the cumulative under-five mortality prevalence experienced by each woman. Because there are few instances of under-five mortality during the previous 60 months in this sample, the distribution is highly skewed towards 0. For Aim 1, we create a binary variable of under-five mortality. A respondent is assigned a 1 if she experienced one or more deaths among those children who were born in the previous 60 months. She is assigned a 0 if she experienced no under-five deaths among her children in the 60-month period. For Aim 2, instead, we wish to estimate the predicted number of under-five deaths under different FP scenarios. Therefore, we maintain the information as a count variable in order to easily input the predicted values into the population projection calculations.

**Region-level under-five mortality rate**: The DHS documentation defines this rate as the quotient calculated by dividing the number of deaths at ages 0-5 by the number of children alive at the beginning of the 60-month period (Rutstein et al., 2006).

Traditional procedures to calculate under-five mortality rates often do not fully account for cohort and period effects. To adjust estimates for these effects, we use an
alternative strategy for calculating under-five mortality rates (Rajaratnam et al., 2010). This method: 1) approximates the average length of exposure to mortality from a mother's set of children using maternal age; 2) uses cohort and period measures of the fraction of children ever born who died; and 3) takes into account country and regional variations in the age pattern of fertility and mortality. The resulting values are country-specific under-five mortality rates adjusted for cohort and period effects between 1985 and 2009. The procedures described allow researchers to calculate the under-five mortality rate for the entire country. We modified the syntax to obtain region-specific rates.

The first step in this process calculates the cohort-adjusted predicted under-five mortality rate in each region, using the Maternal Age Cohort-Derived Method (MAC). In each of the 182 strata (seven age groups in 26 regions), the estimate is calculated by dividing the number of deceased children by the number of children ever born within the previous 60-month period. This stratification allows the timing of the child's death to be a function of: a) maternal age, b) the proportion of children who died within a region, and c) the fertility patterns in the region's population. Also, the younger age groups report higher-than-average levels of under-five mortality episodes (Schellenberg et al., 2008; Finlay et al., 2011). Stratification by maternal age group corrects the estimated rates for this sub-population.

The second step in this process calculates the region-specific, period-adjusted distribution of births and childhood deaths for mothers in each age group who have had a specific number of children. This step calls for the Maternal Age-Period Derived
Method (MAP). The resulting value is a period-based under-five mortality rate for each year prior to the survey (from 1985 to 2009 when using the 2010 DHS sample). This method allows for more precise estimates of under-five mortality rates in the younger age group (which includes fewer mothers than the older groups).

The last step calls for the Combined Method, which applies a Loess local regression on the estimates generated by the MAC and MAP methods. The objective is to systematically combine the estimates without restricting the predictions to a linear trend over time. The resulting value is a region-specific under-five mortality rate adjusted for both cohort and period effects for each year from 1985 to 2009. For this study, only the region-specific values for 2009 are retained.

### 6.4 Exposure measure

#### 6.4.1 Contraceptive methods

The exposure variable in this study is the prevalence of family planning (FP) use in each region of Tanzania. The contraceptive methods reported in the 2010 DHS are: oral contraceptives, injectable contraceptives, male and female condoms, male and female sterilization, intra-uterine devices (IUD), implant contraceptive (e.g., Norplant), lactational amenorrhea, periodic abstinence, withdrawal, and traditional methods (e.g., herbs, ash concoctions). The interviewer asks which method the respondent uses (if any). While the survey item allows for multiple answers, only 40 respondents out of 2,537 current FP users report using more than one contraceptive method. For the purposes of this study, then, we consider FP methods to be mutually exclusive categories.
6.4.2 Groupings

While it would be preferable to assess the effect of each FP method on fertility and under-five mortality, the small prevalence reported for some methods (namely: male sterilization, female condoms, IUD, Norplant and traditional methods) do not allow for individual assessments. Instead, FP methods are grouped into five mutually exclusive categories: oral contraceptives; injectable contraceptives; barrier methods; permanent and semi-permanent methods; and traditional methods (Table 6.1).
### Table 6.1 Family planning groupings, based on each method's advocacy strategy, effectiveness and medical requirements

<table>
<thead>
<tr>
<th>Family planning groups</th>
<th>Contraceptives</th>
</tr>
</thead>
<tbody>
<tr>
<td>oral contraceptive</td>
<td>oral contraceptives (i.e., &quot;the pill&quot;)</td>
</tr>
<tr>
<td>injectable contraceptives</td>
<td>Injectable contraceptives</td>
</tr>
<tr>
<td>barrier methods</td>
<td>male condom, female condom</td>
</tr>
<tr>
<td>surgical methods</td>
<td>male sterilization, female sterilization, intrauterine device, implants</td>
</tr>
<tr>
<td>traditional methods</td>
<td>withdrawal, periodical abstinence, lactational amenorrhea, local herbs</td>
</tr>
</tbody>
</table>
These groupings have been previously used in both family planning and HIV interventions and observational studies based in Tanzania (Guttmacher, 2010; Morrison et al., 2007; Ngure et al., 2011). They are based on each method's advocacy strategy, effectiveness and medical requirements.

- Traditional methods require no medical practitioner or healthcare expertise, since they rely on timing or strategies suggested by older female relatives and traditional healers. They can be employed any time there is a stock-out at the local clinic, or limited economic/time resources do not allow women to acquire other methods. They are also sought when modern methods are believed to have severe side effects (e.g., pains/weakness, cancer development, permanent infertility, etc.). They have a very low reported effectiveness: around 50% (Stover et al., 2005).

- Barrier methods are advocated as a strategy to prevent HIV infection, and do not need to be acquired through a medical practitioner. Indeed, they are available in pharmacies, stores, and the offices of non-governmental organizations. Among this population, condoms are generally associated with prevention of sexually transmitted infections rather than contraception (Plummer et al., 2010). They are preferred by younger women, who often are not married and therefore select their protection practices on a case-by-case basis. Their effectiveness in preventing pregnancy is around 81%, since they often used incorrectly (Stover et al., 2000; 2005).

- Oral contraceptives require monthly interaction with medical personnel when acquiring a package (30-day supply). This method is mostly used by younger women to space pregnancies farther apart. Women in all age groups report using this method to
limit the number of pregnancies as well. Full adherence requires daily doses, and effectiveness is around 92% (Stover et al., 2005).

- Injectable contraceptives also require interactions with medical practitioners. However, protection is guaranteed for three months through a single dose. Users can easily conceal their actions from family members. Users of this method tend to be younger women who want to space pregnancies farther apart, or older women who want to limit the number of children. Their effectiveness in reported to be 100% (Stover et al., 2005).

- Surgical methods require a medical practitioner to perform the operation. Because the goal is usually to limit pregnancies or space them far apart, these strategies are preferred by older women who have already achieved their parity goals. They are expensive procedures, and often require that users either travel great distances to a clinic that undertakes the operation or wait for a mobile clinic to come to the village. Concealment is very difficult. Their effectiveness is 100% (Stover et al., 2005).

6.4.3 Measurements

Like the outcome variables, FP use is assessed using two measures:

Individual use: each FP group is categorized as a binary variable, where 1 indicates that the respondent is a current user of a specific FP grouping and 0 indicates that she is not a user of a method in that particular group.

Region-specific prevalence: This measure records the proportion of respondents in each region who currently employs one of the contraceptive methods. This measure is defined as the number of women who currently use a method in a specific FP group, divided by
the total number of women in the sample. We calculate region-specific proportions, thus obtaining proportions for the five FP groupings for each of the 26 regions. Also, for each FP grouping, we calculate proportions stratified by both region and maternal age to account for different method preference at different ages in a woman's reproductive life. This stratification scheme allows us to calculate proportions for the five FP groupings for each of the 26 regions and each of the seven age groups (for a total of 910 values).

6.5 Covariates

In this study, we employ covariates to reduce bias in the association of interest, and to increase the precision of the estimates. When selecting covariates for model adjustment, we considered a number of options before choosing the variables we believe most strongly impact the association of interest. On one hand, we want to account for as many potential confounders as possible. On the other, we want to ensure that all model assumptions are met, and that there are no sparsely populated cells where adjustment techniques cannot be applied without heroic assumptions. In the end, we select covariates for each type of adjustment we want to implement: stratification, matching, or regression adjustment.

6.5.1 Stratification variables

Stratification allows us to assess effect measure modification. That is, we evaluate whether the association of interest varies across strata of the covariates. For this study, the stratifying covariates selected are maternal age (divided into 5-year age groups) and region or residence. Fertility and under-five mortality rates, as well as FP methods used, vary considerably across strata of these variables. It is imperative to assess how the
association varies across these levels, and therefore which policies should be implemented in each.

Maternal age: Fertility varies by age because biological fecundity varies with age. Social, behavioral or motivational determinants of fertility also vary with age. The age structure within the 15-49 age range may vary substantially across populations, thus justifying the computation of age-specific rates (Preston et al., 2001). Furthermore, maternal age can strongly influence under-five mortality among a woman's children. These events tend to be more prevalent among mothers at the tails of the age distribution (Finlay et al., 2011; Rajaratnam et al., 2010). Region-level measures of total fertility rate and under-five mortality rate already incorporate explicit adjustment for maternal age (see Sections 6.2.1 and 6.2.2). Individual-level measures, instead, must be stratified by maternal age to obtain age-specific prevalence values. Finally, previous research suggests that FP method choice differ by the user's age. Maternal age influences reproductive goals, and therefore a woman's choice to space, limit, or increase her number of pregnancies. For example, younger women prefer oral contraceptives and condoms, while older women prefer permanent and semi-permanent methods (Chen et al., 2003).

Region of residence: Residence location influences whether a household is an agricultural/pastoral one or if it relies on commerce, how much funding is invested in the children's education, and the degree of connectivity between urban centers and villages. Northern districts are generally better educated and more gainfully employed than the Southern ones, due to the high-volume traffic of tourists and non-governmental organizations in the Serengeti and Kilimanjaro areas (Keefe, 2006). It follows that the
social context is more permissive towards FP strategies in the northern regions compared to the southern ones. Therefore, the association of interest is likely to vary considerably in both magnitude and direction across different regions.

6.5.2 Matching variables

Matching procedures make the distribution of potential confounding factors identical between exposed and non-exposed units, so that the two groups are exchangeable. For this study, the matching covariates selected are the respondent's educational attainment (whether or not she completed primary school), her household wealth index quintile value, and the urban/rural status of her dwelling within a region. These variables are potential confounders of the association of interest because they strongly influence a woman's reproductive options, as well as her reproductive goals (DHS, 2010). They compose the social and environmental context in which women select their FP options, and therefore affect their fertility and under-five mortality outcomes (Coleman, 1990).

**Urban/rural status:** A respondent's level of urbanization is defined by whether she lives in the urban or rural area of her region of residence. Previous studies suggest that fertility and under-five mortality, as well as FP prevalence, vary according to the level of urbanization in which the respondent lives (Ezeh et al., 2009; Shapiro et al., 2008). This variable would have been a valid candidate for stratification. However, there are far fewer respondents in the urban areas compared to the rural areas. After stratifying on maternal age and region of residence, stratification on urban status would have created many sparsely populated cells and made urban area estimates unstable. Nonetheless, a respondent's urban status influences both fertility outcomes and FP choices, and therefore
cannot be ignored. We use this information to match respondents, and therefore create homogeneity between exposed and non-exposed women between and within their region of residence.

**Educational attainment**: This variable is usually defined as whether or not the respondent completed the last grade of primary school, which corresponds to grade Standard 7 in the Tanzanian educational system. The literature suggests that there is a strong association between education and falling fertility rates. More highly educated women use effective contraceptive methods more frequently and consistently, have their first child at a later age, space their pregnancies farther apart, and consequently have fewer children and fewer under-five deaths compared to women with a lower educational attainment (Kravdal et al., 2001; Larsen et al., 2003; Marchant et al., 2004; Hollos et al., 2004; Chen et al., 2003; Ezeh et al., 2009). Educational attainment is a strong confounder of the associations of interest, and can severely bias their magnitude and direction if not take into account. By matching respondents on whether or not they completed primary school we increase homogeneity between the matched observations and eliminate this source of bias.

**Wealth index**: The wealthier a household, the more disposable income it has for expenditures like contraceptives (Cleland et al., 2006). Also, wealthier households tend to adopt more Western standards of living, and thus often prefer smaller families – where more resources can be devoted to each child (Kravdal et al., 2001; Habib, 2008; McTavish et al., 2010). Therefore, both fertility and under-five mortality events are fewer in wealthier households compared to poorer ones. As such, household wealth is a
potential confounder of the associations of interest (Chen et al., 2003; Hargreaves et al., 2007; Ezeh et al., 2009). As with urban status and educational attainment, we match respondents on their reported household wealth index value to increase homogeneity between matched observations and eliminate this source of bias.

The 2010 DHS releases a measure of household wealth, which is an indicator of the level of wealth that is consistent with expenditure and income measures (Rutstein, 1999). In developing countries, cash flow is limited (Hargreaves et al., 2007; Morris et al., 2000). Therefore, this index captures the different household assets and dwelling characteristics owned by a household. These are: floor materials, water supply, sanitation facilities, electricity, radio, television, telephone, refrigerator, type of vehicle, number of persons per sleeping room, ownership of agricultural land, and presence of domestic servants (Rutstein et al., 2004). It has been tested in a number of countries in relation to inequities in household income, use of health services, and health outcomes (Rutstein et al., 2004; Rutstein et al., 2000). It is calculated by first standardizing the indicator variables and calculating z-scores. Then the factor coefficient scores (i.e., factor loadings) are calculated. Finally, for each household, the indicator values are multiplied by the loadings and summed to produce the household's wealth index value. Only the first of the factors produced is used to represent the wealth index. The resulting sum is a standardized score with a mean of 0 and a standard deviation of 1 (Filmer et al., 2001). The resulting wealth index is divided into quintiles. The cut points in the wealth index are calculated by obtaining a weighted frequency distribution of households. The weight is the product of the number of de jure members (i.e., persons who are legal residents of the
household) and the sampling weight of the household. The distribution represents the
national household population, where each member is given the wealth index score of his
or her household. The persons are ordered by the score, and the distribution is divided at
the points that form the five 20% sections. Then the household score is recoded into the
quintile variable so that each member of a household also receives that household's
quintile category (Rutstein et al., 2004).

6.5.3 Adjustment variables

We use stratification and matching covariates to reduce heterogeneity in the
association of interest. Residual confounding is mitigated by employing the information
on maternal occupation to further adjust the association in the linear regression models. A
woman's profession is defined as her involvement in no economic activity, farming, or
other activities (e.g., commerce, service). Farming is singled out because half of DHS
respondents report engaging in this activity exclusively. This variable is a likely
confounder of the association of interest, but most of its effect is mostly taken into
account by the education and wealth covariates in the matching process. Therefore, we
include maternal occupation in the linear regression model only as an additional
adjustment step to capture residual confounding.

6.5.4 Variables excluded

When selecting covariates, we discarded a number of potential candidates for various
reasons. Some of these candidates were not collected in the 2010 DHS dataset (i.e.,
respondent's religious affiliation). Others are strongly associated with covariates already
selected, and therefore are redundant in the model. One example is source of FP method,
which is strongly associated with a respondent's wealth quintile, educational attainment, and region of residence (Chen et al., 2003).

Information on a woman's number of children surviving is a particular case of potential confounder that is not included among the matching variables of this study. On the one hand, it is strongly associated with both the exposure and the outcomes. Indeed, women select a FP method based on the number of children they already have (i.e., number of children currently surviving), as well as the number of additional children they want to meet their reproductive goals (i.e., total number of children at the end of their reproductive life). On the other hand, number of children surviving is a time-varying predictor that both influences and is influenced by a woman's total number of children. Therefore, this variable is part of a circular argument with both fertility and under-five mortality variables. As such, it should not be included in the models. Indeed, the linear regression models do not converge when we account for this variable. This is a clear sign that the estimates are unstable.

6.6 Specific Aim 1

The first aim assesses the independent effect of each FP method on: 1) the total fertility rate (TFR); and 2) the under-five mortality rate of each region in Tanzania. The objective is to identify the FP methods that most effectively curb parity and under-five mortality, while accounting for the regional context in which women live.

6.6.1 Matching

If the exposure of interest were independent of all covariates, we would not need to control for potential confounders. Any parametric analysis would be reduced to a
difference in means of the outcomes of interest between the exposed and non-exposed groups. However, this is not an easy assumption to make. In this study, to assume that there is no association between FP choice and the background characteristics of respondents prevents us from empirically examining the research question of interest.

Nonetheless, potential confounders must be taken into account when estimating the independent effect of FP methods on fertility and under-five mortality. Matching is a process where the distribution of one or more potential confounding factors is identical between exposed and non-exposed units of analysis. Its goal is to prune observations from the data so that the remaining information has better balance between the exposed and non-exposed groups. In other words, this pre-processing step allows the distribution of the covariates in each group to be more similar (Blackwell et al., 2009). Then, the actual relationship between the potential confounder and the exposure of interest is eliminated. If matching is performed on strong confounders, exposed and non-exposed units are identical to one another on all characteristics except the exposure variable. As a result, the estimates reflect less model dependence, lower bias, reduced homogeneity, and increased efficiency (Ho et al., 2007; Iacus et al., 2008).

When matching, we selectively drop observations from the data. We do so without inducing bias, as long as the potential confounders do not depend on the outcome variable. The observations to be dropped represent respondents who could never be exposed to a certain type of FP methods. Therefore, matching for these units is not possible because they have no counterfactual. This situation is called structural
confounding (Messer et al., 2010). Once matching is performed, the resulting values are never crude estimates. Rather, they are adjusted for all matching variables.

Matching has some weaknesses: 1) when multiple variables are being used, it may be difficult to find suitable matches – hence we avoid 1:1 matches in favor of matches within specified ranges; 2) matching implies that the study groups are somewhat tailored: this increases internal validity but reduces external validity; 3) the association between the outcomes of interest and the matching variables cannot be assessed; and 4) there is no increase in statistical power if the matched variables are weak confounders (Rothman et al., 2008).

6.6.2 Linear regression models

When we match observations, we do not perform a 1:1 match because we do not want to restrict the dataset to perfect matches only – too many observations would be dropped. Rather, we allow units to be matched within certain ranges of the covariates' parameters. While this step can greatly improve the precision of the estimates, it does not eliminate all confounding because the units may not be perfect matches for one another. To solve this issue, we run linear regression models using the matched dataset. Here, we adjust the associations of interest by the matching covariates (to remove the confounding due to imperfect matches) and by other, weaker confounders to further reduce heterogeneity in the association of interest.

This two-step process allows the analysis to be "doubly robust". First, covariates are selected as matching parameters to make the units of analysis exchangeable. Second, covariates also are included in the linear regression model to further improve
exchangeability. The estimates' precision is increased by this double process. If either the matched analysis or the regression model is correctly specified (but not necessarily both), the resulting inferences are statistically consistent (Ho et al., 2011).

This advantage makes matching a suitable strategy to answer the research question of Aim 1. We use this approach in three different models to assess the effect of each FP method under different specifications of the regional context. We first match regions (region-level model); then respondents within regions (individual-level model); and finally respondents across the country (hybrid model). Figure 6.1 summarizes the steps in each model's implementation.
Figure 6.1 Analytic strategy for each model designed to answer Specific Aim 1

<table>
<thead>
<tr>
<th>Model name</th>
<th>Region-level model</th>
<th>Individual-level model</th>
<th>Hybrid model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model specification</td>
<td>The entire region is either exposed or not exposed to a specific FP method.</td>
<td>Women within a specific region are either exposed or not exposed to a specific FP method.</td>
<td>Women across the country are either exposed or not exposed to a specific FP method.</td>
</tr>
<tr>
<td>Pre-processing strategy</td>
<td>match regions</td>
<td>match women within regions</td>
<td>match women across regions</td>
</tr>
<tr>
<td>Matching variables</td>
<td>urban status primary school completion average wealth index score</td>
<td>urban status primary school completion average wealth index score</td>
<td>urban status primary school completion average wealth index score</td>
</tr>
<tr>
<td>Statistical package</td>
<td>R 2.12</td>
<td>Stata 11.1</td>
<td>Stata 11.1</td>
</tr>
<tr>
<td>Command</td>
<td>MatchIt, Zelig</td>
<td>psmatch2</td>
<td>psmatch2</td>
</tr>
<tr>
<td>Output</td>
<td>Average causal effect of a specific FP method on treated regions, compared to non-treated regions</td>
<td>Average causal effect of a specific FP method on treated women, compared to non-treated women, conditional on the regional effect</td>
<td>Average causal effect of a specific FP method on treated women, compared to non-treated women, regardless of the regional effect</td>
</tr>
</tbody>
</table>
6.6.3. Region-level model

In this model, we compare regions of Tanzania to assess the independent effect of region-specific FP prevalence on the region's total fertility rate (TFR) and under-five mortality rate. In the idealized experiment, all residents of a region are randomized together to either the exposed or non-exposed arm (Cox, 1958). The goal is to assess the effect of the regional context on individual's FP choices. Given this set-up, the independent effect of FP on fertility and under-five mortality would be a simple difference in means. However, both ethics and feasibility preclude this strategy.

The best alternative strategy is to match regions on their background characteristics. Matched regions will be considered exchangeable: that is, they are considered identical on all factors except for their exposure to FP methods. Then the idealized experiment can be mimicked with observational data. To accomplish this, we identify which regions are considered to be "exposed" to a certain FP group, and which ones can be classified as "non-exposed". First, we collapse the dataset to the region level, so that all variables are region-specific averages of the values in the full dataset. Second, we divide the regions into quintiles based on their prevalence of use of a specific FP method. Regions in the two quintiles with the highest prevalence of use are considered to be in the "exposed" arm, and are assigned a 1. Regions in the two quintiles with the lowest prevalence of use are considered to be in the "non-exposed" arm, and are assigned a 0. The new dichotomous variable represents the treatment condition that would have been assigned to each region if the idealized experiment had been possible. Regions in the middle quintile are excluded from analysis, so that there is a clear demarcation between the two arms in
this idealized experiment. Quintiles are preferred to tertiles because the former eliminates fewer regions from the analysis than the latter, while still creating a clear division between exposed and unexposed regions. We repeat this procedure for each FP grouping, generating different quintile compositions for the experimental arms of each comparison.

Third, we pre-process the data by matching exposed and non-exposed regions on region-specific proportion of urban residents, primary school graduates, and average wealth quintile. For each FP grouping and outcome of interest, we create a matched dataset using the R package MatchIt – which allows users to match observations on potential confounders, thus minimizing the possibility of bias. The only requirement for these confounders is that they be associated with the exposure but not be dependent on the outcomes. Otherwise, selection bias is introduced when creating the matches (Ho et al., 2011). Through different model specifications, it is possible to discard observations that have no appropriate matches, as well as to match one region to one or more regions, depending on the distribution of the covariates (Ho et al., 2011).

The matching procedure could be done manually by pairing regions based on the distribution of their background characteristics. However, the MatchIt package: 1) considers all possible matches between regions, and selects the most appropriate pairings given specifications; 2) produces summary statistics that allow users to evaluate the dataset's improvement in balance; 3) allows regions to be matched or discarded based on approximate matching through a genetic algorithm; and 4) creates a matched dataset for the subsequent linear regression models.
Fourth, we calculate the average causal effect (ACE), which is the independent effect of a specific FP grouping on the TFR and under-five mortality rate. For this calculation, we use the R package *Zelig* to run a linear regression that has the TFR or the under-five mortality rate as the outcome of interest, the prevalence of a specific FP grouping as the exposure, and covariates to adjust the estimates (Imai et al., 2007). Covariates included the variables used for the matching procedures (i.e., urban status, primary school completion and wealth index) to control for the residual confounding that still remains after the approximate matching. Additionally, we include another covariate (i.e., maternal occupation) that we do not consider to be as strong a confounder as the matching variables, but nonetheless can account for residual confounding and improve the precision of the estimates (Ho et al., 2011). We repeat this analysis for each FP grouping within each outcome. These procedures result in 10 ACE estimates.

### 6.6.4 Individual-level model

The goal of Specific Aim 1 is to assess the independent effect of region-specific FP prevalence on TFR and under-five mortality rate. However, both the exposure and the outcomes of this study are measured at the individual level. Therefore, it could be argued that an individual-level analysis is a valid alternative to the regional model described above. In the individual-level model, we compare individuals within their regions of residence to assess the independent effect of individual FP use on individual measures of fertility and under-five mortality, conditional on the regional effect. In the idealized experiment, residents within a region are randomized to either the exposed or non-exposed arm. The goal is to assess the effect of individual FP choices on individual
fertility and under-five mortality outcomes, conditional on the regional context in which women live. In this set-up, the independent effect of FP on fertility and under-five mortality would be a simple difference in means. However, both ethics and feasibility preclude this strategy.

The best alternative strategy is to match respondents within a region on their background characteristics. Matched respondents are considered exchangeable. Then the idealized experiment can be mimicked with observational data. Within each region, women exposed to FP are those who report currently using a contraceptive method included in one of the FP groupings. Non-exposed women are those who report using no contraceptives at the time of the interview. The new dichotomous variable represents the treatment condition that would have been assigned to each respondent, if the idealized experiment had been possible.

Within each regional stratum, we match respondents on primary school completion status, urban status, and average wealth index score. We employ the `psmatch2` command in Stata 11.1, which implements full Mahalanobis matching and a variety of propensity score matching methods to adjust for pre-treatment observable differences between exposed and non-exposed respondents (Leuven et al., 2003). Calipers are set to 0.05. We generate an ACE value for the whole population by averaging the ACE values obtained from each region. We repeat this analysis for each FP grouping within each outcome. These procedures result in 10 ACE estimates.
6.6.5 Hybrid model

In both the nested and crossed models, matching strategies take into account the regional context in which FP choices are made – whether it be between regions or within them. The resulting estimates are adjusted for this contextual effect. However, it is unclear how these estimates would change if the contextual effect were not taken into consideration. In other words, what would be the independent effect of different FP methods on fertility and under-five mortality if we considered all women within Tanzania to be exchangeable without regard for geographical boundaries? In the hybrid model, we compare women across Tanzania to assess the independent effect of individual FP use on individual measures of fertility and under-five mortality. This model is called "hybrid" because it does not attempt to disentangle regional effects from individual effects when estimating the effect of a specific FP method on fertility and under-five mortality events.

In the idealized experiment, residents across the country are randomized to either the exposed or non-exposed arm. The goal is to assess whether or not the effect of individual FP choices on individual fertility and under-five mortality outcomes is independent of a woman's specific regional context. In an idealized experiment, it would be possible to randomly assign women across Tanzania to either a specific FP method (the exposed arm) or to no contraceptive (the non-exposed arm). Then, the independent effect of FP on fertility and under-five mortality would be a simple difference in means. However, both ethics and feasibility preclude this strategy.

The best alternative strategy is to match respondents on their background characteristics. Matched respondents will be considered exchangeable. Then the idealized
experiment can be mimicked with observational data. Women exposed to FP are those who report currently using a contraceptive method included in one of the FP groupings. Non-exposed women are those who report using no contraceptives at the time of the interview. The new dichotomous variable represents the treatment condition that would have been assigned to each respondent, if the idealized experiment had been possible.

Analytic procedures for the hybrid models are similar to those used in the individual-level models. First, we employ individual-level records in the 2010 DHS dataset, but we do not stratify observations by region. Second, we match respondents on primary school completion, urban status, and average wealth index score. We employ the `psmatch2` command in Stata 11.1 for this analysis as well. Calipers are set to 0.05. Third, we obtain an ACE estimate for the whole population. Because we obtain a single value for the entire country, no variance is calculated around the estimate. Therefore, we bootstrap the standard error of the estimate to obtain confidence intervals for the country's ACE value. We repeat this analysis for each FP grouping within each outcome. These procedures result in 10 ACE estimates.

6.7 Specific Aim 2

The second aim of this study re-calculates Tanzania's population projections (from 2010 to 2025) for different proportions of each FP method's use. The objective is to assess the prevalence of each FP method that would be necessary to decrease the country's population growth trends.

This aim requires several analytical steps. First, we calculate the sample's predicted average number of births in each stratum of maternal age, given different proportions of
use for each FP grouping. We repeat the procedures to obtain the predicted average number of under-five death events. Second, we use the country's estimates for age-specific fertility rate (ASFR) and under-five mortality rate to estimate the predicted number of births and under-five mortality events for the entire population. Lastly, we use the cohort-component population projection method to estimate the country's total population in five-year intervals, given different FP methods and prevalence values. We employ population projections rather than life series analysis because: a) the 2010 DHS data are cross-sectional instead of longitudinal; and b) we are interested in the change in population size as both current and new FP users reduce their individual fertility events. If we had used two iterations of the DHS to perform time series analyses, we would have had to aggregate observations at the regional level, thus losing fertility information at the individual level.

6.7.1 Coefficients estimation

The objective of this first step is to re-estimate population projections for Tanzania by calculating the number of births that would occur if different proportions of the female population used different contraceptive methods. The first outcome of interest is the average number of births that occurred in the 36 months before the interview within each maternal age stratum. This time restriction has two reasons: a) the objective of this step is to provide the predicted total number of births for the population projections estimates, which are grouped in five-year intervals. Hence the outcome variable should consider only recent births, rather than children ever born; and b) the DHS uses the 36-month cutoff point in its age-specific fertility rate calculations as a compromise between recency
and reduction of sampling variation. For comparison's sake, we maintain the cut-off. The second outcome of interest is the average number of under-five deaths that occurred in the 60 months before the interview within each maternal age stratum. This time restriction stems from the need to provide the predicted total number of under-five deaths for the population projections estimates, which are grouped in five-year intervals. Hence the outcome variable considers only recent deaths, rather than all deceased children younger than five years.

For both outcomes, the procedural steps follow the same pattern. First, we stratify the sample on five-year maternal age group, thus obtaining seven strata. We stratify by age group because we want the final estimates to be adjusted by age-specific risk. The proportion of contraceptive users in each stratum is the independent variable. Wealth quintile, educational attainment and urban/rural status are the stratum-specific covariates. The number of births in the previous 36 months, stratified by age group and region of residence, is the first dependent variable. The number of under-five deaths in the previous 60 months, stratified by age group and region of residence, is the second dependent variable. If we had stratified the outcome variables by maternal age group only, we would have estimated the average number of events per individual woman in each age group. Summary statistics would have calculated the sum of the average number of events per woman in each age group. Instead, by stratifying the outcome variables by maternal age group and region of residence, we obtain the average number of births and under-five deaths per region for each age group. Summary statistics, then, calculate the sum of the average number of events per region in each age group. The estimated distributions of
these summary statistics mirror the descriptive distributions of births and under-five
deaths by maternal age in the sample.

Second, we pre-process the dataset for each FP method. The goal is to discard regions
that have no counterfactual on the covariates of interest. This step is performed manually
by comparing the covariates' distributions between regions that are either exposed or non-
exposed to a specific FP method. Finally, we run 70 linear regression models (five FP
groupings within each of the seven maternal age strata, for the two outcomes of interest).
In each model, we request robust standard errors. We ignore sample weights to avoid
overestimating the sampling variances and confidence intervals of oversampled groups
(Rutstein et al., 2006).

Third, we multiply each contraceptive method's coefficient by different proportions of
use in the age group. Current FP prevalence is progressively increased by 1%, 2%, 7%
(i.e., the proportion of women in the sample who state they have an unmet need for FP to
limit their number of pregnancies), 12% (i.e., the proportion of women in the sample who
state they have an unmet need for FP to space their pregnancies farther apart), and 19%
(i.e., the total proportion of women in the sample who state they have an unmet need for
FP). To the resulting value, we add the coefficients for urban status, wealth and
education, multiplied by their corresponding stratum-specific proportions (Westoff,
2006). The resulting estimates are the age-specific: a) predicted average number of births
per region in the previous 36 months; and b) predicted average number of under-five
deaths per region in the previous 60 months, given different proportions of contraceptive
use for each FP method and adjusted for the three covariates. We sum each of these two
values across age groups to obtain the sample's total predicted number of births and under-five deaths per region.

6.7.2 Cohort component population projection method

Population projections are estimates of future trends in the number and composition of persons in a given place and time (Lutz, 2010). The most commonly used technique for estimating future population growth trends is the component population projection method (Notestein, 1945). This method estimates the future population of an area given the current population, its birth rate, death rate, and migration. It assumes that the size of a future population depends on the current size of the population, plus the number of births in a specified interval of time and the number of immigrants to the area, minus the number of deaths occurring in the time interval of interest (Hollmann et al., 2000). The equation is:

\[ \text{Pop}_{2025} = \text{Pop}_{2010} + \text{Birth}_{2010-2025} - \text{Death}_{2010-2025} + \text{Migration}_{2010-2025} \]

It is strongly recommended that predictions be made in five-year intervals to avoid extrapolating projections based on long-term assumptions. The result of the first projection can be used to perform the second round of the projection, and so on (Measure Evaluation, 2011). The literature also recommends dividing the total population in five-year age groups (from 0 to 80+), since different cohorts are differentially exposed to the risk of fertility and mortality (Preston et al., 2001).

There are three steps to using the cohort component method. First, we gather age-specific information for both the current and predicted population of Tanzania. Current information is reported in the 2010 DHS dataset. Predicted information for subsequent
years is compiled by the Tanzania National Bureau of Statistics, which produces and releases region-specific population projections, subdivided in single- and five-year age intervals, for each year between 2002 and 2025 (NBS, 2002). The first step of the projections uses the number of persons in each age subgroup that will be alive in 2015, given population values in 2010. The 2010 and 2015 distributions are aligned so that, for example, women ages 20-24 in 2010 are the same persons as the women ages 25-29 in 2015. Second, we divide the population in each 2015 age subgroup by the population in each 2010 age subgroup. This way, we know the proportion of women alive in 2010 who survived to 2015: this is the survival rate of the age subgroup. We use these age-specific survival rates to project the population of Tanzania forward by five-year increments (Measure Evaluation, 2011). We assume that these rates will remain constant throughout the 2010-2025 period considered for this study.

6.7.3 FP-adjusted population projections

The World Health Organization (WHO) and Tanzania's National Bureau of Statistics (NBS) routinely estimate population projections for different regions of the country (WHO, 2009; NBS, 2002). However, they do not take into account the potential effect of increasing FP prevalence on future population size. The third step of the cohort component method is to add the number of predicted births and deaths that take place in the projection interval. We use the age-specific predicted number of births in the previous 36 months – given different proportions of contraceptive use for each FP method – we previously calculated from the 2010 DHS.
These input values are calculated based on DHS sample values, and therefore reflect the predicted number of births and deaths over the projection interval in the sample only. To obtain the population-level predicted values, we use these values to calculate estimates of ASFR and under-five mortality rates under different FP scenarios (see Section 6.2.1). Because the DHS sample is representative of the population at large, these descriptive values of fertility and under-five mortality apply to both the sample and the population (DHS 2010). These FP-derived estimates of ASFR do not exactly match the descriptive values obtained from the sample. While the denominator values are the same, the FP-derived estimates use as their numerator the average number of births per region multiplied by 26 (obtained from the linear regression models) rather than the observed number of births across the country. Therefore, while the relationship between each FP method and the number of births in the population is the same as that in the DHS sample, the absolute number of births tends to be inflated.

For each maternal age sub-group, we multiply the ASFR value by the number of women-years at risk of pregnancy in the population during the projection interval. The person-year value is obtained by summing the number of women in each maternal age group in each of the preceding three years (2008, 2009, and 2010) across regions, as reported by the NBS projections (NBS, 2002). The resulting value is the number of children expected to be born in the projection interval from women in a specific age group across Tanzania. We sum these projected values across age groups to obtain the overall number of predicted births. We repeat this procedure using the under-five
mortality rate to estimate the number of under-five children expected to die in the 5-year projection interval to women of a specific age group across Tanzania.

Finally, we substitute each of these FP-specific birth values to the population size in the 0-5 age group of 2010. We use the same estimated number of children entering the population for each year of the projection (2010, 2015, 2020, and 2025). Our final population size in 2025 does not match the one reported by NBS because we hold constant the number of births in the five-year interval. In reality, this number is expected to increase with each passing year. Also, we assume that the effectiveness of each FP method will not vary over time, and that its impact on fertility will remain constant in each five-year interval. The resulting values of population size at each interval allow us to draw a projection of the population of Tanzania under different FP scenarios.

6.8 Sensitivity analysis

The results of the qualitative study we conducted in Tanzanian villages in the summer of 2010 suggest that answers on FP use are subjected to social desirability bias. This bias is defined as a respondent's reluctance to admit using contraceptives because of attitudes, beliefs and perceptions held in her community and her family. During the focus groups, many respondents said that they would answer truthfully to questions on FP use only if the DHS interviews were conducted in private. If another person were in the room at the time of the interview, respondents said they would likely minimize their reported use of contraceptives. This would be done to avoid conflict with higher-ranking relatives (i.e., husbands, mothers-in-law) who value high parity.
The 2010 DHS documentation states that sensitive information, such as FP use, should be collected in private. If privacy cannot be ensured, the interviewer is instructed to skip the module and end the interview (DHS, 2010). However, privacy is difficult to obtain in small dwellings and tight-knit communities (Kidolezi et al., 2009). Indeed, only 69.5% of interviews were privately held. There is no privacy information for the remaining 30.5% of the interviews (DHS, 2010). Therefore, the reported FP use in this second sub-sample may be biased towards the null, depending on whether another person was present at the time of the interview.

Given the information we collected in the focus groups and the known sensitivity of FP items, we hypothesize that the DHS data include social desirability bias. Skewed information would include a lower prevalence of each FP method. Estimates of each FP method's effect on fertility and under-five mortality events would be skewed towards the null. We assume that interviews conducted in private elicited a higher degree of honesty from respondents, who are more willing to admit to using contraceptives if they can be guaranteed confidentiality. Then, a sub-sample that comprises only interviews conducted in the private would be free of such bias. Therefore, the purpose of this sensitivity analysis is to assess the magnitude of the potential social desirability bias in the DHS sample. To test this assumption, we repeat the analyses for Aim 1 using only the sub-sample that was reportedly interviewed in private. The goal is to assess whether there are differences between the Aim 1 results and those calculated from this sub-samples. Changes in magnitude or direction suggest the presence of social desirability bias in the full DHS dataset. If this difference exists, lack of privacy could be a serious concern for
data collection on FP usage. This information can be used to strengthen the DHS' privacy requirement when collecting information on sensitive topics. On the other hand, if the estimates from the full DHS dataset are not significantly different from those calculated using the sub-sample, we suggest that lack of privacy is not necessarily a deterrent when interviewing village women on FP.

6.9 Summary

In summary, we define the variables chosen as the exposure, outcomes and covariates for this study, and justify their inclusion in the models. We also describe the analytic processes we implement to answer Specific Aim 1 (assess the independent effect of each FP method on the total fertility rate and the under-five mortality rate of each region in Tanzania) and Specific Aim 2 (re-calculate Tanzania's population projections for different proportions of each FP method's use). We draw from both the epidemiology and DHS literature to select the most appropriate methods to estimate the country's total fertility rate and under-five mortality rates, stratified by maternal age group and region of residence. We rely on the latest data pre-processing strategies to obtain more precise estimates of FP effectiveness in curbing parity and under-five mortality. We employ validated demographic methods to re-estimate the future size of the Tanzanian population given the impact of different FP methods. Finally, we run a sensitivity analysis to assess the presence and magnitude of social desirability bias in the sample.
7. Results

7.1 Overview

The research question this dissertation addresses is whether a woman's fertility would change if 1) the type of family planning (FP) method used; and 2) the prevalence of use were to vary under alternate social and environmental conditions. This chapter presents the results obtained from the analytic strategy described in Section 6. First, we report a description of the DHS sample, including the distribution of the association of interest across maternal age and region of residence. Second, we present the results of Aim 1, where we estimate the average causal effect of each FP method on the total fertility rate and the under-five mortality rate. Third, for Aim 2, we present the number of births and under-five mortality events that would occur if different proportions of women used a specific FP method. Also, we re-estimate population projections for the country given different scenarios of contraceptive use. Finally, we describe the sensitivity analysis run to assess the impact of social desirability bias on respondents' answers.

7.2 Descriptive statistics

7.2.1 Sample description

The 2010 iteration of the Demographics and Health Surveys (DHS) questionnaire includes 10,139 women ages 15 to 49. All 26 regions of Tanzania are included. Over-sampling in smaller regions, coupled with sample weights applied to descriptive statistics, allow sample estimate to be representative of the population at large. Table 7.1 presents respondents’ characteristics across strata of maternal age and region of residence. Values vary greatly across maternal age groups. Younger mothers completed primary
school in higher proportions (73%), compared to the older cohorts. Also, fewer older women live in urban settings compared to the younger cohorts. Finally, average wealth scores seem to be uniformly distributed across the age groups.
Table 7.1 Weighted sample description, by region of residence and maternal age group

<table>
<thead>
<tr>
<th>Region</th>
<th>Primary school</th>
<th>Wealth index&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Urban status</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dodoma</td>
<td>52%</td>
<td>2.19</td>
<td>11%</td>
<td>495</td>
</tr>
<tr>
<td>Arusha</td>
<td>71%</td>
<td>3.23</td>
<td>30%</td>
<td>401</td>
</tr>
<tr>
<td>Kilimanjaro</td>
<td>93%</td>
<td>3.96</td>
<td>28%</td>
<td>411</td>
</tr>
<tr>
<td>Tanga</td>
<td>65%</td>
<td>3.15</td>
<td>24%</td>
<td>498</td>
</tr>
<tr>
<td>Morogoro</td>
<td>65%</td>
<td>3.23</td>
<td>32%</td>
<td>481</td>
</tr>
<tr>
<td>Pwani</td>
<td>62%</td>
<td>3.11</td>
<td>32%</td>
<td>261</td>
</tr>
<tr>
<td>Dar es Salaam</td>
<td>86%</td>
<td>4.77</td>
<td>92%</td>
<td>866</td>
</tr>
<tr>
<td>Lindi</td>
<td>49%</td>
<td>2.09</td>
<td>15%</td>
<td>198</td>
</tr>
<tr>
<td>Mtwara</td>
<td>65%</td>
<td>2.36</td>
<td>22%</td>
<td>407</td>
</tr>
<tr>
<td>Ruvuma</td>
<td>84%</td>
<td>3.18</td>
<td>18%</td>
<td>350</td>
</tr>
<tr>
<td>Iringa</td>
<td>74%</td>
<td>3.53</td>
<td>25%</td>
<td>490</td>
</tr>
<tr>
<td>Mbeya</td>
<td>71%</td>
<td>3.39</td>
<td>22%</td>
<td>623</td>
</tr>
<tr>
<td>Singida</td>
<td>72%</td>
<td>2.35</td>
<td>19%</td>
<td>317</td>
</tr>
<tr>
<td>Tabora</td>
<td>51%</td>
<td>2.37</td>
<td>11%</td>
<td>447</td>
</tr>
<tr>
<td>Rukwa</td>
<td>55%</td>
<td>2.46</td>
<td>17%</td>
<td>257</td>
</tr>
<tr>
<td>Kigoma</td>
<td>60%</td>
<td>2.85</td>
<td>31%</td>
<td>462</td>
</tr>
<tr>
<td>Shinyanga</td>
<td>52%</td>
<td>2.54</td>
<td>17%</td>
<td>819</td>
</tr>
<tr>
<td>Kagera</td>
<td>58%</td>
<td>2.69</td>
<td>7%</td>
<td>590</td>
</tr>
<tr>
<td>Mwanza</td>
<td>54%</td>
<td>2.90</td>
<td>27%</td>
<td>844</td>
</tr>
<tr>
<td>Mara</td>
<td>74%</td>
<td>2.86</td>
<td>15%</td>
<td>376</td>
</tr>
<tr>
<td>Manyara</td>
<td>64%</td>
<td>2.49</td>
<td>10%</td>
<td>220</td>
</tr>
<tr>
<td>Zanzibar North</td>
<td>49%</td>
<td>3.37</td>
<td>0%</td>
<td>50</td>
</tr>
<tr>
<td>Zanzibar South</td>
<td>73%</td>
<td>3.82</td>
<td>5%</td>
<td>30</td>
</tr>
<tr>
<td>Town West</td>
<td>84%</td>
<td>4.80</td>
<td>81%</td>
<td>131</td>
</tr>
<tr>
<td>Pemba North</td>
<td>45%</td>
<td>2.96</td>
<td>8%</td>
<td>56</td>
</tr>
<tr>
<td>Pemba South</td>
<td>60%</td>
<td>3.56</td>
<td>27%</td>
<td>59</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Maternal age</th>
<th>Primary school</th>
<th>Wealth index&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Urban status</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>15-19</td>
<td>72%</td>
<td>3.24</td>
<td>27%</td>
<td>2,173</td>
</tr>
<tr>
<td>20-24</td>
<td>65%</td>
<td>3.08</td>
<td>31%</td>
<td>1,908</td>
</tr>
<tr>
<td>25-29</td>
<td>66%</td>
<td>3.16</td>
<td>30%</td>
<td>1,668</td>
</tr>
<tr>
<td>30-34</td>
<td>69%</td>
<td>3.18</td>
<td>30%</td>
<td>1,422</td>
</tr>
<tr>
<td>35-39</td>
<td>63%</td>
<td>2.78</td>
<td>20%</td>
<td>1,290</td>
</tr>
<tr>
<td>40-44</td>
<td>71%</td>
<td>2.94</td>
<td>23%</td>
<td>938</td>
</tr>
<tr>
<td>45-49</td>
<td>47%</td>
<td>2.76</td>
<td>17%</td>
<td>740</td>
</tr>
</tbody>
</table>

<sup>a</sup> Average wealth index score, calculated from the DHS household wealth quintiles
Regions vary in their proportion of educational attainment, urban status, and average wealth indicator. The Dar es Salaam and Town West regions have the highest average wealth index values (4.77 and 4.80, respectively), while Lindi has the lowest (2.09). The region with the highest proportion of respondents who completed primary school is Kilimanjaro (93%), while the region with the lowest proportion of educated women is Pemba North (45%). Dar es Salaam has the highest urban concentration (92%), while the island of Zanzibar has the lowest (5%).

7.2.2 Exposure variables

The exposure variable for this study is current use of a family planning (FP) method among reproductive age women. Approximately 29% of respondents reported using a method. These are: oral contraceptives, injectable contraceptives, male and female condoms, male and female sterilization, intra-uterine devices, implants, periodic abstinence, withdrawal, and lactational amenorrhea. As reported in Section 6.3.2, we pool methods into five groups according to their efficacy and advocacy strategy. Grouping allows us to overcome small prevalence values for some of the lesser used methods. Therefore, FP methods are grouped into five mutually exclusive categories: oral contraceptives; injectable contraceptives; barrier methods, permanent and semi-permanent methods; and traditional methods (see Table 7.2). Groups can be considered mutually exclusive because only 40 women in the sample reported using more than one FP method at the time.
Table 7.2 Types of family planning methods, with weighted frequency and proportion of use

<table>
<thead>
<tr>
<th>FP method</th>
<th>Freq</th>
<th>Prop</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>7,222</td>
<td>71.23</td>
</tr>
<tr>
<td>Oral contraceptive</td>
<td>521</td>
<td>5.14</td>
</tr>
<tr>
<td>Injectable contraceptive</td>
<td>860</td>
<td>8.49</td>
</tr>
<tr>
<td>Barrier methods</td>
<td>431</td>
<td>4.25</td>
</tr>
<tr>
<td>Surgical methods</td>
<td>484</td>
<td>4.77</td>
</tr>
<tr>
<td>Traditional methods</td>
<td>621</td>
<td>6.13</td>
</tr>
</tbody>
</table>
Stratification by maternal age group reveals that preference for a certain FP method over another varies with the age of the user (Table 7.3). The majority of women use no method at all (71%) – especially in the youngest and oldest age categories. Among those who use contraceptives, each age stratum displays preference for specific FP methods. For example, women age 25-35 seem to select injectable contraceptives most often, followed by oral contraceptives and traditional methods. Women in their forties, instead, prefer permanent methods – supposedly because they have reached their ideal number of children and look to limit the number of future pregnancies.
Table 7.3 Distribution of family planning methods' prevalence of use, by maternal age group (row %)

<table>
<thead>
<tr>
<th>Maternal age group</th>
<th>Oral methods</th>
<th>Injectable methods</th>
<th>Barrier methods</th>
<th>Permanent Methods</th>
<th>Traditional methods</th>
<th>No methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>15-19</td>
<td>1%</td>
<td>2%</td>
<td>6%</td>
<td>0%</td>
<td>1%</td>
<td>89%</td>
</tr>
<tr>
<td>20-24</td>
<td>5%</td>
<td>9%</td>
<td>6%</td>
<td>2%</td>
<td>6%</td>
<td>71%</td>
</tr>
<tr>
<td>25-29</td>
<td>7%</td>
<td>14%</td>
<td>4%</td>
<td>3%</td>
<td>8%</td>
<td>64%</td>
</tr>
<tr>
<td>30-35</td>
<td>8%</td>
<td>13%</td>
<td>3%</td>
<td>6%</td>
<td>9%</td>
<td>61%</td>
</tr>
<tr>
<td>35-39</td>
<td>8%</td>
<td>9%</td>
<td>3%</td>
<td>7%</td>
<td>8%</td>
<td>65%</td>
</tr>
<tr>
<td>40-44</td>
<td>7%</td>
<td>8%</td>
<td>2%</td>
<td>12%</td>
<td>8%</td>
<td>63%</td>
</tr>
<tr>
<td>45-49</td>
<td>2%</td>
<td>4%</td>
<td>1%</td>
<td>13%</td>
<td>4%</td>
<td>76%</td>
</tr>
</tbody>
</table>
The selection of a contraceptive method also varies according to respondents' characteristics. Table 7.4 reports the proportions of FP users who completed primary school. It also reports the proportion of FP users who live in an urban area, the proportion of users who are farmers, as well as the average score on the wealth index. The table is stratified by contraceptive type, to assess whether users of different FP methods (if any) vary on these socio-demographic characteristics.

Among women who do not use any form of contraceptive, 62% completed primary school and only 27% live in urban areas. Conversely, women who use an FP method report higher proportions of primary school completion (from 72% among those who use traditional methods to 86% among those who use condoms). Contraceptive users also live in urban areas in higher proportions (from 32% among those who use oral contraceptives to 43% among those who use condoms). Among farmers, the difference between users and non-users is not as pronounced. Among non-users, 55% are farmers. Among users, the range varies between 32% (condom users) and 53% (oral contraceptives). Finally, wealth index scores vary little between users and non-users. Non-users report a score of 3.40, while users range between 3.28 (oral contraceptives) and 3.92 (condom users).

These descriptive statistics suggest that women who do not use any form of FP tend to live in rural areas and be less educated. Among contraceptive users, different FP methods seem associated to different socio-demographic characteristics. For example, women who use condoms tend to live in urban areas and complete primary school more often compared to other FP users. A lower proportion of them report farming as their main occupation, and report higher wealth. Conversely, compared to other FP users, women
who choose oral contraceptives tend to live in rural areas, list farming as their main occupation more often, and report lower wealth scores.
Table 7.4 Weighted frequency and proportion of the sample's educational attainment (primary school completion: yes/no), urban/rural status, occupation (farmer: yes/no), and average wealth index value, stratified by family planning method

<table>
<thead>
<tr>
<th>FP method currently in use</th>
<th>Primary School</th>
<th>Urban Status</th>
<th>Occupation</th>
<th>Wealth Index&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>completed</td>
<td>not completed</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Freq (Row %)</td>
<td>Freq (Row %)</td>
<td>Freq (Row %)</td>
<td>Freq (Row %)</td>
</tr>
<tr>
<td>None</td>
<td>4,511</td>
<td>2711</td>
<td>1,867</td>
<td>5355</td>
</tr>
<tr>
<td></td>
<td>62%</td>
<td>38%</td>
<td>26%</td>
<td>74%</td>
</tr>
<tr>
<td>oral contraceptives</td>
<td>407</td>
<td>114</td>
<td>168</td>
<td>353</td>
</tr>
<tr>
<td></td>
<td>78%</td>
<td>22%</td>
<td>32%</td>
<td>68%</td>
</tr>
<tr>
<td>Injectables</td>
<td>623</td>
<td>237</td>
<td>286</td>
<td>575</td>
</tr>
<tr>
<td></td>
<td>72%</td>
<td>28%</td>
<td>33%</td>
<td>67%</td>
</tr>
<tr>
<td>barrier methods</td>
<td>368</td>
<td>62</td>
<td>183</td>
<td>247</td>
</tr>
<tr>
<td></td>
<td>86%</td>
<td>14%</td>
<td>43%</td>
<td>57%</td>
</tr>
<tr>
<td>surgical methods</td>
<td>362</td>
<td>121</td>
<td>140</td>
<td>343</td>
</tr>
<tr>
<td></td>
<td>75%</td>
<td>25%</td>
<td>29%</td>
<td>71%</td>
</tr>
<tr>
<td>traditional methods</td>
<td>446</td>
<td>175</td>
<td>248</td>
<td>373</td>
</tr>
<tr>
<td></td>
<td>72%</td>
<td>28%</td>
<td>40%</td>
<td>60%</td>
</tr>
<tr>
<td>Total</td>
<td>6,718</td>
<td>3421</td>
<td>2,892</td>
<td>7247</td>
</tr>
<tr>
<td></td>
<td>66%</td>
<td>34%</td>
<td>29%</td>
<td>71%</td>
</tr>
</tbody>
</table>

<sup>a</sup> Average wealth index score, calculated from the DHS household wealth quintiles
7.2.3 Outcome variables

Fertility and under-five mortality values also vary considerably between regions (Table 7.5). Total fertility rate (TFR) is defined as the average number of births per woman that a respondent would have by the time she reaches age 50, if she were to give birth at the current age-specific fertility rates (DHS, 2010). The regions of Shinyanga and Rukwa have the highest reported TFR values (7.5), while Kilimanjaro and Zanzibar South have the lowest (3.2 and 3.1, respectively). The country's TFR is 5.7 (DHS, 2010). The under-five mortality rate is the quotient calculated by dividing the number of deaths at 0-5 age range by the number of children alive at the beginning of the 60-month period (DHS, 2010). Mara experiences 158.4 under-five deaths per 1,000 live births, while Kilimanjaro reports only 35 deaths per 1,000 live births. The country's most recent value for under-five mortality rate is 91 per 1,000 live births in 2009 (DHS, 2010). The region-specific TFR and under-five mortality rates of this population are positively correlated (Pearson correlation = 0.16; p = 0.001). This result supports findings in the literature, where higher average number of children per woman is associated with a higher under-five mortality rate.
Table 7.5 Total fertility rates and under-five mortality rates, by regions of Tanzania

<table>
<thead>
<tr>
<th>Region</th>
<th>TFR</th>
<th>U5 Mortality Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dodoma</td>
<td>7.2</td>
<td>99.9</td>
</tr>
<tr>
<td>Arusha</td>
<td>4.3</td>
<td>61.3</td>
</tr>
<tr>
<td>Kilimanjaro</td>
<td>3.2</td>
<td>35.0</td>
</tr>
<tr>
<td>Tanga</td>
<td>5.1</td>
<td>120.0</td>
</tr>
<tr>
<td>Morogoro</td>
<td>5.1</td>
<td>108.5</td>
</tr>
<tr>
<td>Pwani</td>
<td>5.1</td>
<td>82.1</td>
</tr>
<tr>
<td>Dar es Salaam</td>
<td>4.3</td>
<td>99.9</td>
</tr>
<tr>
<td>Lindi</td>
<td>4.3</td>
<td>154.3</td>
</tr>
<tr>
<td>Mtwara</td>
<td>4.0</td>
<td>126.7</td>
</tr>
<tr>
<td>Ruvuma</td>
<td>4.8</td>
<td>85.3</td>
</tr>
<tr>
<td>Iringa</td>
<td>4.8</td>
<td>135.3</td>
</tr>
<tr>
<td>Mbeya</td>
<td>7.0</td>
<td>85.9</td>
</tr>
<tr>
<td>Singida</td>
<td>6.2</td>
<td>68.1</td>
</tr>
<tr>
<td>Tabora</td>
<td>5.5</td>
<td>82.8</td>
</tr>
<tr>
<td>Rukwa</td>
<td>7.5</td>
<td>91.2</td>
</tr>
<tr>
<td>Kigoma</td>
<td>6.7</td>
<td>101.8</td>
</tr>
<tr>
<td>Shinyanga</td>
<td>7.5</td>
<td>73.4</td>
</tr>
<tr>
<td>Kagera</td>
<td>6.1</td>
<td>100.7</td>
</tr>
<tr>
<td>Mwanza</td>
<td>6.8</td>
<td>80.2</td>
</tr>
<tr>
<td>Mara</td>
<td>6.0</td>
<td>158.4</td>
</tr>
<tr>
<td>Manyara</td>
<td>6.0</td>
<td>55.5</td>
</tr>
<tr>
<td>Zanzibar North</td>
<td>4.7</td>
<td>87.5</td>
</tr>
<tr>
<td>Zanzibar South</td>
<td>3.1</td>
<td>72.7</td>
</tr>
<tr>
<td>Town West</td>
<td>3.6</td>
<td>69.3</td>
</tr>
<tr>
<td>Pemba North</td>
<td>5.6</td>
<td>88.4</td>
</tr>
<tr>
<td>Pemba South</td>
<td>4.9</td>
<td>85.4</td>
</tr>
</tbody>
</table>
Fertility and under-five events also vary by maternal age group. As shown in Figure 7.1, most of the 5,013 births that occurred in the 36 months prior to the DHS interview were reported by younger women ages 20-24. The number of births sharply declines as women's age – and therefore fertility – increases. Women in the youngest group have far fewer births compared to women in the following age cohorts. This occurs because most women in the youngest age cohort are not yet married (the average age at first marriage is 18.4 years). Therefore, most of them have not had a chance to become pregnant yet.
Figure 7.1 Weighted number of births in the sample during the 36 months prior to the DHS interview, by maternal age group.
Under-five mortality events also are differentially distributed across maternal age groups. A total of 3,774 under-five mortality events were reported for the previous 60 months. As shown in Figure 7.2, women ages 35-39 report the highest proportion of under-five deaths experienced in the sample. The number of deaths declines sharply in subsequent cohorts, since older women are likely to have more grown children compared to younger women. Therefore, any mortality event among their older offspring is not reported here. Among younger cohorts, the number of under-five deaths increases steadily as the number of children born to these women increases as well.
Figure 7.2 Weighted number of under-five deaths in the sample during the 60 months prior to the DHS interview, by maternal age group
7.3 Specific Aim 1

The first aim of this study assesses the independent effect of each FP method on the total fertility rate and the under-five mortality rate for regions of Tanzania. The objective is to identify the FP methods that most effectively curb a region's TFR and under-five mortality rate. We present the average causal effect of each FP method (ACE) on total fertility rate and the under-five mortality rate. We assess the region's effect on FP choices by comparing regions deemed to be exposed to a specific FP method to regions that are not considered exposed. See Section 6.5.3 for a description of the regions' assignment to condition arm.

7.3.1 Matching

Logistical and ethical reasons forbid us to randomly allocate women to a region of residence in order to expose them to a specific contraceptive method. Therefore, known and unknown covariates are not balanced across intervention arms, and observations have no observable counterfactual substitute. Nonetheless, we want to maintain the experimental design framework to estimate the average causal effect of each FP method on fertility and under-five mortality. Therefore, we pre-processed the data through matching (see Section 6.5.1 for a complete description of the matching process). The goal to increase the precision of the estimates by eliminating those regions that have no counterfactual given the matching variables selected (i.e., primary school completion, average wealth index score, urban status). After matching, the distribution of the covariates in each group is more similar, and the relationship between the potential confounder and the exposure of interest is eliminated (Blackwell et al., 2009). As a
result, the estimates reflect less model dependence, lower bias, reduced homogeneity, and increased efficiency (Ho et al., 2007; Iacus et al., 2008). We use the R statistical package *MatchIt* to match regions on these covariates, as well as to eliminate regions that were not considered exchangeable with the others in the sample.

### 7.3.2 Fertility

First, we estimate the average causal effect (ACE) of each FP method on fertility. The ACE is defined as the treatment effect between those who were assigned to the exposure arm compared to those who were assigned to the control arm (Hernán, 2004; Maldonado et al., 2002). We prefer this measure of treatment effect to the average treatment effect on the treated (ATT). This latter measure assesses the average gain from treatment for those who actually were treated (Iacus et al., 2008).

The model designed to address Specific Aim 1 compares regions on their exposure to each of the FP methods. Its objective is to assess how the contextual effects created by regional characteristics engender differential access to contraceptive resources, and consequentially differential total fertility rate. For this purpose, we assume that all women within a region share the same exposure status to the FP method under consideration.

Table 7.6 reports the contraceptive-specific ACE values and confidence intervals. This between-regions model suggests that only permanent FP methods are expected to reduce the total fertility rate (TFR) of a region, when compared to non-exposed regions. In other words, regions classified as exposed to permanent FP methods are expected to report a reduction in their TFR value compared to non-exposed regions. This suggests
that the 1.59 reduction in TFR between exposed and non-exposed regions is attributable to the permanent FP methods applied in the exposed regions. This result confirms previous reports in the literature, where permanent methods are listed as the most effective contraceptive strategy. Their effectiveness in preventing pregnancies is 100% (Stover et al., 2005), and they require a single application (in the case of surgical sterilization) or very few visits to the clinic (in the case of implants and IUDs). Discontinuation, then, is highly unlikely, and the risk of pregnancy is all but eliminated. Oral contraceptives and injectable contraceptives also seem to reduce the TFR of exposed regions, but their effect does not reach statistical significance.

7.3.3 Under-five mortality

Second, we estimate the average causal effect (ACE) of each FP method on the under-five mortality rate. The same between-region comparison is modeled. We want to assess how the contextual effects created by regional characteristics engender differential access to contraceptive resources, and consequentially differential under-five mortality rate. Once again, we assume that all women within a region share the same exposure status to the FP method under consideration.

Table 7.7 reports the contraceptive-specific ACE values and confidence intervals. Results suggest that the under-five mortality rate of regions exposed to any of the FP methods is higher compared to that of non-exposed regions. However, none of these differences between exposed and non-exposed regions reach statistical significance. Therefore, we do not expect any of the FP methods under consideration to significantly reduce the under-five mortality rate of exposed regions, compared to non-exposed
regions. This null result is somewhat surprising, considering the importance of pregnancy spacing for child survival (Yeakley et al., 2009; Rutstein et al., 2005).

7.3.4 Regional context specification

The regional context specified in both the total fertility rate and under-five mortality rate models is designed to account for the environmental effects created by regional characteristics, which in turn may engender differential access to contraceptive resources. However, this is only one of the regional context definitions that we can apply to this research question. Other definitions may produce different estimates, thus changing the conclusions of the study. It is particularly important to assess potential differences in estimates when the regional context is defined in terms of individual characteristics. Both the exposure and the outcomes of interest concern individual women. It would be useful to assess whether different regional context definitions engender different estimates for the same model specifications. Hence, we run the same model for each outcome, but now we seek exchangeability at the individual level: first within regions, and second across the country. By toggling between these definitions of the regional context, we examine the same associations under different regional conditions. Variations in the results suggest that model specification for the regional context strongly affects the estimates of FP methods' impact.

Fertility: The first alternative regional context specification compares users and non-users of each FP method within their region of residence. The objective is to assess the impact of individual characteristics on FP choices, conditional on the specific regional context in which respondents live. The ACE estimates from this model suggest that all FP
methods tend to reduce a woman's number of children once the regional context is taken into consideration. However, none of these methods are expected to impact on individual women's fertility. Individual women exposed to any one of these FP methods are not expected to experience a reduction in their parity when compared to non-users, after accounting for regional effects. These results suggest that the specific context in which women live (i.e., their region of residence) accounts for most of the effect of FP methods on individual fertility events. Once it is taken into account, individual characteristics explain only a small portion of the remaining variance.

The second alternative regional context specification compares users and non-users of each FP method across Tanzania, without regard for the region in which respondents live. It assumes that women are perfectly exchangeable regardless of their location of residence, and that individual characteristics alone determine FP choices. Oral contraceptives, barrier methods and permanent methods are expected to reduce an individual woman's number of children. For example, a reduction of 0.57 children for each woman can be attributed to oral contraceptives. Injectable contraceptives and traditional methods also seem to reduce a woman's number of children, but this difference between exposed and non-exposed women does not reach statistical significance. These results suggest that, when the regional context is ignored, individual characteristics account for a large portion of the variance among users of oral contraceptives, barrier methods and permanent methods. The latter method produced statistically significant estimates in the between-regions model as well, so its adoption seems to be driven by both regional factors and individual characteristics. The uptake of
oral contraceptives and barrier methods, instead, seems mostly driven by individual characteristics.

Table 7.6 compares the ACE estimates generated from the three different regional context definitions. Each model specification produces different ACE estimates at varying levels of statistical significance. Therefore, we posit that the regional context definition strongly impacts the ACE estimates for fertility. This implies that regional characteristics play an important role in the selection of a contraceptive method. Hence, they should be given great consideration when assessing the impact of each FP method on fertility events.
Table 7.6 Average causal effect of different family planning methods on fertility, for different model specifications

<table>
<thead>
<tr>
<th>Between Regions</th>
<th>Total Fertility Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ACE</td>
</tr>
<tr>
<td>Oral contraceptives</td>
<td>-1.03</td>
</tr>
<tr>
<td>Injectable contraceptives</td>
<td>-0.54</td>
</tr>
<tr>
<td>Barrier methods</td>
<td>0.17</td>
</tr>
<tr>
<td>Permanent methods</td>
<td>-1.59</td>
</tr>
<tr>
<td>Traditional methods</td>
<td>0.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Within Regions</th>
<th>Children born in prior 36 mo.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ACE</td>
</tr>
<tr>
<td>Oral contraceptives</td>
<td>-0.02</td>
</tr>
<tr>
<td>Injectable contraceptives</td>
<td>-0.04</td>
</tr>
<tr>
<td>Barrier methods</td>
<td>-0.01</td>
</tr>
<tr>
<td>Permanent methods</td>
<td>-0.07</td>
</tr>
<tr>
<td>Traditional methods</td>
<td>-0.09</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Across Tanzania</th>
<th>Children born in prior 36 mo.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ACE</td>
</tr>
<tr>
<td>Oral contraceptives</td>
<td>-0.57</td>
</tr>
<tr>
<td>Injectable contraceptives</td>
<td>-0.30</td>
</tr>
<tr>
<td>Barrier methods</td>
<td>-0.40</td>
</tr>
<tr>
<td>Permanent methods</td>
<td>-0.30</td>
</tr>
<tr>
<td>Traditional methods</td>
<td>-0.31</td>
</tr>
</tbody>
</table>
**Under-five mortality:** The same alternative regional context definitions specified for fertility outcomes are applied to the under-five mortality outcome. The first alternative regional context specification compares users and non-users of each FP method within their region of residence. Barrier methods, permanent methods and traditional methods are expected to reduce the number of under-five deaths experienced by individual women, but none of the ACE estimates reach statistical significance. As with the fertility estimates, these results suggest that the specific context in which women live (i.e., their region of residence) accounts for most of the effect of FP methods on individual under-five mortality events. Once it is taken into account, individual characteristics explain only a small portion of the remaining variance.

The second alternative regional context specification compares users and non-users of each FP method across Tanzania, without regard for the region in which respondents live. Results reiterate the findings from the previous two models: none of the FP methods are expected to impact the number of under-five mortality events experienced by a woman exposed to a contraceptive method, when compared to non-exposed respondents. Therefore, when the regional context is ignored, the individual characteristics that influence FP choice do not seem to impact whether a woman experiences an under-five mortality event.

Table 7.7 compares the ACE estimates generated from the three different regional context definitions. Each model specification produces ACE estimates at the same level of statistical significance. Therefore, we posit that the regional context definition does not impact the ACE estimates for fertility. Regional characteristics may play a role in the
selection of a contraceptive method, but their effect on under-five mortality events is minimal.
Table 7.7 Average causal effect of different family planning methods on under-five mortality, for different model specifications

<table>
<thead>
<tr>
<th></th>
<th>Between Regions</th>
<th>Within Regions</th>
<th>Across Tanzania</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Under-five mortality rate</td>
<td>U5 children deceased in prior 60 m</td>
<td>U5 children deceased in prior 60 m</td>
</tr>
<tr>
<td></td>
<td>ACE</td>
<td>95% CI</td>
<td>ACE</td>
</tr>
<tr>
<td>Oral contraceptives</td>
<td>9.23</td>
<td>(-19.05, 34.00)</td>
<td>0.04</td>
</tr>
<tr>
<td>Injectable contraceptives</td>
<td>3.54</td>
<td>(-35.18, 39.95)</td>
<td>0.01</td>
</tr>
<tr>
<td>Barrier methods</td>
<td>9.46</td>
<td>(-31.23, 49.09)</td>
<td>-0.07</td>
</tr>
<tr>
<td>Permanent methods</td>
<td>16.91</td>
<td>(-35.44, 60.27)</td>
<td>-0.01</td>
</tr>
<tr>
<td>Traditional methods</td>
<td>0.28</td>
<td>(-28.26, 28.21)</td>
<td>-0.05</td>
</tr>
</tbody>
</table>
7.4 Specific Aim 2

The second aim of this study re-calculates Tanzania's population projections (from 2010 up to 2025) for different proportions of each FP method's use. The objective is to assess the prevalence of each FP method that would be necessary to reduce the country's population growth trends. First, we present the results for the number of births that would have occurred in the 36 months prior to the DHS interview if different proportions of FP use had been implemented in the population. Second, we present the results for the number of under-five deaths that would have occurred in the 60 months prior to the DHS interview if different proportions of FP use had been implemented. Finally, we use the cohort component population projection method (described in Section 6.6.2) to re-estimate the predicted population projections under different FP scenarios.

7.4.1 Number of births predicted, by FP method

We estimate the number of children who would have been born in the previous 36 months had different FP scenarios been implemented. To calculate these values, we first created region-specific estimates of the outcome (number of children born in the previous 36 months), the exposure (prevalence of a specific FP method), and the covariates (proportion of women who completed primary school, proportion of women living in an urban area, and average wealth index score). All models were stratified by maternal age group, to allow the association of interest to vary across levels of maternal age. Second, we manually pre-processed the data to retain in the analysis only those regions that had a reasonable counterfactual in the sample. Third, we run linear regression models for each age group and for each FP method, so to obtain the coefficients that describe the
relationship between the outcome and the exposures for each FP scenario. Fourth, we calculated the predicted number of births that would have occurred in the previous 36 months if different proportions of FP use had been used. We progressively increase the prevalence of FP use, from the current proportion of use to an increase in prevalence of 19% in each maternal age group. See Section 6.6.1 for a more detailed description of the analytic process. Figure 7.3a-e reports the number of births in the population that would have occurred in the previous 36 months under different FP scenarios.

**Oral contraceptives:** Increases in the prevalence of oral contraceptives have the greatest impact among younger women. Indeed, among women ages 15-19, the number of births would be reduced to almost 0 if prevalence of use were increased by 12% or more. We also saw dramatic decreases in fertility among women ages 20-24 and 25-29. If oral contraceptive prevalence were increased by 19% in the first group, the number of births in the previous 36 months would be reduced from 1,705,525 to 197,679. In the second group, the same increase in prevalence would reduce the number of births form 1,543,783 to 285,185. Conversely, oral contraceptives minimally affect the fertility of older women. Among women ages 40-44, the number of births would be reduced from 307,222 to 275,638. In the oldest age group, the reduction in the number of births is even smaller; from 79,914 to 76,467. Women in the middle age groups also report decreases in the number of children born in the previous 36 months. However, the declines due to increased prevalence of use are not as dramatic as for the younger groups (see Figure 7.3a).
Injectable contraceptives: The effect of injectable contraceptives on fertility in the past 36 months is very similar to that described for oral contraceptives. Increases in the prevalence of injectable contraceptives have the greatest impact among younger women. Indeed, among women ages 15-19, the number of births would be reduced from 732,808 to 54,380 if prevalence of use were increased by 19%. We also saw decreases in fertility among women ages 20-24 and 25-29 – although not as dramatic as for oral contraceptives. If injectable contraceptive prevalence were increased by 19% in the first group, the number of births in the previous 36 months would be reduced from 1,638,255 to 951,405. In the second group, the same increase in prevalence would reduce the number of births from 1,529,594 to 886,626. Conversely, injectable contraceptives have a smaller effect among older women. Among women ages 30-34, a 19% increase in injectable contraceptive prevalence reduces the number of births by only 125,237 events (see Figure 7.3b).

Barrier methods: Among women using barrier methods (i.e., male and female condoms), the trend is reversed: the higher the increase in FP prevalence, the higher the number of children born in the previous 36 months. The highest increase is seen among women age 30-34, where the number of children born increased from 1,136,197 to 3,393,029 as prevalence of condom use increased. We see the same trend – although not as dramatic – among the three youngest age groups and for women ages 35-39. For women ages 40-49, instead, this trend is almost flat, even though there is still evidence of an increase in fertility as condom prevalence increases. This incremental trend could be due to condoms’ low efficacy (82%) in preventing pregnancies (see Figure 7.3c).
Permanent methods: Increases in the prevalence of permanent methods (i.e., male and female sterilization, implants, intra-uterine devices) have the greatest impact on the fertility of women ages 20-24. Indeed, in this age group, the number of births would be reduced to almost 0 if prevalence of use were increased by 19% or more. We also see a dramatic decrease in fertility among women ages 15-19. If oral contraceptive prevalence were increased by 19% in this group, the number of births in the previous 36 months would be reduced by 528,323 events. Conversely, permanent methods minimally affect the fertility of older women. Among women ages 40-44, the number of births would be reduced from 358,818 to 329,208. In the oldest age group, the reduction in the number of births is even smaller; from 109,764 to 99,380. Women in the middle age groups also report decreases in the number of children born in the previous 36 months. However, the declines due to increased prevalence of use are not as dramatic as for the younger groups (see Figure 7.3d).

Traditional methods: Like with barrier methods, use of traditional methods (i.e., lactational amenorrhea, withdrawal, periodic abstinence) seems to increase – rather than decrease – the number of children born in the previous 36 months. The highest increase is seen among women age 25-29, where the number of children born increased from 1,496,837 to 2,679,980 as prevalence of condom use increased. A very similar scenario occurs among women age 20-24, where the number of births increases from 1,584,032 to 2,613,412 as prevalence of traditional methods increases. We see the same trend – although not as dramatic – in all other age groups. The trend for older women is nearly flat, but we still observe an increase in the number of children born. This incremental
trend could be due to traditional methods' low efficacy (50%) in preventing pregnancies. These results confirm findings previously reported in the literature (Ijaiya et al., 2009) (see Figure 7.3e).
Figure 7.3a-e Number of births accrued in 36 months given different proportions of family planning use, stratified by maternal age group. The first column of each group represents the number of children born under the current FP prevalence of use, while the last column represents the number of children born if the age-specific prevalence of use were increased by 19%. The intermediate columns represent prevalence increases of 1%, 2%, 7%, and 12%, respectively.

a. Oral contraceptives

![Graph showing age-specific number of births in Tanzania by different proportions of oral contraceptives' use]

b. Injectable contraceptives

![Graph showing age-specific number of births in Tanzania by different proportions of injectable contraceptive method's use]
c. Barrier methods

Age-specific number of births in Tanzania by different proportions of barrier methods' use

d. Permanent methods

Age-specific number of births in Tanzania by different proportions of permanent contraceptive methods' use
e. Traditional methods

![Graph: Age-specific number of births in Tanzania by different proportions of traditional contraceptive methods' use](image)

- Number of births by different age groups (15-19, 20-24, 25-29, 30-34, 35-39, 40-44, 45-49) and birth use by traditional contraceptive methods.
7.4.2 Number of under-five deaths predicted, by FP method

We assessed the number of under-five children who would died in the previous 60 months had different FP scenarios been implemented. The strategy to estimate is the same as the one described in Section 7.4.1 for number of births. The only difference is that the outcome of interest is the number of under-five children deceased in the previous 60 months, rather than number of children born in the previous 36 months. Figure 4a-e reports the number of under-five deaths in the population that would have occurred in the previous 60 months under different FP scenarios.

**Oral contraceptives:** Increases in the prevalence of oral contraceptives have the greatest impact among women in the middle maternal age groups. Among women ages 30-34, the number of under-five deaths would be reduced to almost 0 if prevalence of use were increased by 19% or more. Among women age 35-39, the decrease is as dramatic, with under-five deaths falling by 69,846 events. We also see dramatic decreases in under-five mortality among women ages 20-24 and 25-29, and, to a lesser extent, among women age 40-44. If oral contraceptive prevalence were increased by 19% in the first group, the number of under-five deaths in the previous 60 months would be reduced by 22,544. In the second group, the same increase in prevalence would reduce the number of births to almost 0. In the third group, the reduction would be of only 17,842 events. Conversely, oral contraceptives minimally affect the number of under-five deaths experienced by the youngest women. This is the group who experiences the fewest under-five death events in the population. Therefore, it is not surprising that oral contraceptives
would have only a limited impact in reducing under-five mortality among these women (see Figure 7.4a).

**Injectable contraceptives:** The effect of injectable contraceptives on under-five mortality in the past 60 months is most noticeable among women ages 25-29 and ages 35-39. Indeed, among women in the first group, the number of under-five mortality events would be reduced to 47,555 from 27,843 if prevalence of use were increased by 19%. Among women in the second group, the decrease would be of 32,901 if injectable contraceptive prevalence were increased by 19%. We also saw decreases in fertility among women ages 45-49. In this group, under-five mortality would be reduced to almost 0 if injectable contraceptive prevalence were increased by 12% or more. Conversely, injectable contraceptives minimally affect the number of under-five deaths experienced by the youngest women. Again, this is the age group who experiences the fewest deaths in the first place, so the lack of impact of injectable contraceptives on under-five mortality is not surprising (see Figure 7.4b).

**Barrier methods:** Among women using barrier methods (i.e., male and female condoms), the trend is reversed: the higher the increase in FP prevalence, the higher the number of under-five children who died in the previous 60 months. The highest increase is seen among women age 25-29, where the number of deceased under-five children increases from 46,773 to 150,004 as prevalence of condom use increased. We see the same trend – although not as dramatic – among all other age groups. Again, condom's low efficacy (82%) in preventing pregnancies could be one of the reasons for such
dramatic increases in under-five mortality when prevalence of this method is increased (see Figure 7.4c).

**Permanent methods:** Increases in the prevalence of permanent methods (i.e., male and female sterilization, implants, intra-uterine devices) have the greatest impact on the under-five mortality experienced by women ages 30-35. Indeed, in this age group, the number of under-five death events would be reduced to almost 0 if prevalence of use were increased by 19% or more. The same holds for the youngest age groups (from 11,728 to almost 0, and from 26,068 to almost 0, respectively). We also see decreases in under-five mortality among the other age groups, but the decline is not as steep. Indeed, the smallest difference in under-five deaths experienced (from 46,445 to 42,814) falls in the 40-44 age group (see Figure 7.4d).

**Traditional methods:** Like with barrier methods, use of traditional methods (i.e., lactational amenorrhea, withdrawal, periodic abstinence) seems to increase – rather than decrease – the number of under-five children who died in the previous 60 months. The highest increase is seen among women age 35-39, where the number of deceased children increased from 77,494 to 109,727 as prevalence of condom use increased. A very similar scenario occurs among women age 25-29 and age 30-34, where the number of births increases from 46,602 to 81,776 and from 54,729 to 90,479, respectively, as prevalence of traditional methods increases. We see the same trend – although not as dramatic – in all other age groups. The trend for the youngest women is nearly flat, but we still observe an increase in the number of deceased children. This incremental trend could be due to
the very low efficacy of traditional methods (50%) in preventing pregnancies (see Figure 7.4e).
**Figure 7.4a-e** Number of under-five deaths accrued in 60 months given different proportions of family planning use, stratified by maternal age group. The first column of each group represents the number of deceased children under the current FP prevalence of use, while the last column represents the number of children born if the age-specific prevalence of use were increased by 19%. The intermediate columns represent prevalence increases of 1%, 2%, 7%, and 12%, respectively.

a. Oral contraceptives

![Age-specific number of under-five deaths in Tanzania by different proportions of oral contraceptives' use](image1)

b. Injectable contraceptives

![Age-specific number of under-five deaths in Tanzania by different proportions of injectable contraceptives' use](image2)
c. Barrier methods

Age-specific number of under-five deaths in Tanzania
by different proportions of barrier methods' use

Number of under-five deaths
0 10,000 20,000 30,000 40,000 50,000 60,000


d. Permanent methods

Age-specific number of under-five deaths in Tanzania
by different proportions of permanent methods' use

Number of under-five deaths
0 10,000 20,000 30,000 40,000 50,000 60,000

e. Traditional methods

![Graph showing age-specific number of under-five deaths in Tanzania by different proportions of traditional methods' use.](image)
7.4.3 Population projection 2010-2025 under different FP scenarios

The goal of Aim 2 of this dissertation is to re-estimate population projections for Tanzania, from 2010 to 2025, under different FP scenarios. To accomplish this, we employ the cohort component population projection methods (described in Section 6.6.2). We estimate the population growth trend using current estimates of births in the previous 36 months. This process describes the projection of the Tanzanian population if no changes in FP prevalence were to occur. In the subsequent steps, we rerun the projections assuming that the new cohort entering the population for every 5-year period equals the number of children born in the previous 36 months under different FP scenarios. These values were reported in Section 7.4.1. By assuming: a) zero net migration; and b) constant age-specific survival rates, we project the population forward in 5-year increments under different conditions of FP method and prevalence. The results describe the different trends in population growth if different FP methods were promoted more or less aggressively in each maternal age group.

Oral contraceptives: As the prevalence of this FP method increases, the size of the projected population decreases. If oral contraceptive prevalence were increased by 19%, the population's growth trend would reverse and we would observe a decline in population size. Under this scenario, the population size would go from 35,106,208 to 32,878,855 between 2010 and 2025. Conversely, if the oral contraceptive prevalence were to remain unvaried, the population size would go from 39,947,920 to 51,791,935 between 2010 and 2025. This is the only FP method for which this reversal occurs (see Figure 7.5a).
**Injectable contraceptives:** As with oral contraceptives, the size of the Tanzanian population is projected to decrease as the prevalence of injectable contraceptives increases. The decrease is gradual, and the population would continue to grow in size regardless of the increase in prevalence applied. However, there is a clear, stable reduction in the exponential growth of the population, to the point where the increase in population for a 19% prevalence increase is 37,555,625, compared to a 42,446,923 increase if the prevalence of injectable contraceptives were to remain stable (see Figure 7.5b).

**Barrier methods:** Given the increase in the number of births given increases in the prevalence of barrier methods, it is not surprising to see this increment reflected in this population projection estimation. If the prevalence of barrier methods were increased by 19%, the population of Tanzania would increase from 47,552,175 in 2010 to 81,496,280 in 2025. This is a much greater exponential population growth compared to that projected to occur if no changes were made to the prevalence of barrier methods. Indeed, population size would far exceed the 110 million prediction estimated for 2050 by the United Nations (see Figure 7.5c).

**Permanent methods:** The population growth trend projected for different proportions of permanent FP methods' use resembles that reported for injectable contraceptives. The decrease is gradual, and the population would continue to grow in size regardless of the increase in prevalence applied. However, there is a clear, stable reduction in the exponential growth of the population, to the point where the increase in population for a
19% prevalence increase is 37,420,702, compared to a 41,919,916 increase if the prevalence of permanent FP methods' were to remain stable (see Figure 7.5d).

Traditional methods: Like with barrier methods, traditional methods do not reduce the exponential growth of the Tanzanian population. Rather, we observe a clear increase in the projected population as the prevalence of traditional methods increases. For example, if the prevalence of barrier methods were increased by 19%, the population of Tanzania would increase from 43,852,175 in 2010 to 67,043,046 in 2025. This is a much greater exponential population growth compared to that projected to occur if no changes were made to the prevalence of barrier methods (see Figure 7.5e).
Figure 7.5a-e Population projection for Tanzania from 2010 to 2025, by different types and prevalence of family planning

a. Oral contraceptives

b. Injectable contraceptives
c. Barrier methods

![Barrier methods chart]

- Current
- plus 1%
- plus 2%
- plus 7%
- plus 12%
- plus 19%

Increase in proportion of FP use

Population of Tanzania

Millions

0 10 20 30 40 50 60 70 80 90

2010
2015
2020
2025

d. Permanent methods

![Permanent methods chart]

- Current
- plus 1%
- plus 2%
- plus 7%
- plus 12%
- plus 19%

Increase in proportion of FP use

Population of Tanzania

Millions

0 10 20 30 40 50 60

2010
2015
2020
2025
e. Traditional methods

![Bar chart showing the population of Tanzania from 2010 to 2025 with different assumptions for the increase in proportion of family planning (FP) use: current, plus 1%, plus 2%, plus 7%, plus 12%, and plus 19%. The chart illustrates how the population changes based on these assumptions.]
7.5 Sensitivity analysis

The purpose of this sensitivity analysis is to assess whether respondents' answers are affected by lack of privacy during the DHS interview, and therefore incorporate social desirability bias (where respondents mold their answers to what they perceive to be a socially acceptable answer, regardless of the truth). If this is the case, the average causal effect (ACE) estimates comparing exposed and non-exposed units on fertility and under-five mortality may be skewed. To assess this possibility, we repeat the analyses run for Specific Aim 1 using only the sub-sample who was interviewed privately (as reported in one item of the DHS questionnaire). This sub-sample includes 7,047 respondents (69.5% of the entire sample). Differences in magnitude or direction of the ACE estimates may indicate the potential presence of social desirability bias. Table 7.8 compared the distribution of FP methods used among women in the full sample to that in the sub-sample who reportedly conducted the interview in private.
<table>
<thead>
<tr>
<th>Method</th>
<th>Full sample</th>
<th>Privacy sub-sample</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Freq</td>
<td>Prop</td>
</tr>
<tr>
<td>None</td>
<td>7,222</td>
<td>71.23</td>
</tr>
<tr>
<td>Oral contraceptives</td>
<td>521</td>
<td>5.14</td>
</tr>
<tr>
<td>Injectable contraceptives</td>
<td>860</td>
<td>8.49</td>
</tr>
<tr>
<td>Barrier methods</td>
<td>431</td>
<td>4.25</td>
</tr>
<tr>
<td>Surgical methods</td>
<td>484</td>
<td>4.77</td>
</tr>
<tr>
<td>Traditional methods</td>
<td>621</td>
<td>6.13</td>
</tr>
</tbody>
</table>
Fewer women report using no contraceptive method in the sub-sample, compared to the full sample. Also, the sub-sample reports a higher prevalence of injectable contraceptives. This method is the most used among married women who wish to space or limit pregnancies, but cannot do so openly because of strongly societal preferences for high parity. It is reasonable that use of these methods should be the most strongly subjected to social desirability bias – and therefore underreporting. There is almost no difference between the full sample and the sub-sample of prevalence of permanent contraceptive methods and barrier methods.

Fertility: In a replication of the total fertility rate (TFR) analysis run for Specific Aim 1, the model compares regions exposed to an FP method to regions that are not exposed. Estimates of ACE values of FP methods on fertility measures are reported in Table 7.9. All contraceptives but traditional methods are expected to reduce the total fertility rate (TFR) of exposed regions, compared to non-exposed regions. However, none of these differences reach statistical significance. In the corresponding ACE values of Specific Aim 1, where the full sample was employed, only permanent FP methods reached significance. This result does not support the hypothesis we state in Section 6.7, namely that the DHS data incorporates social desirability bias due to lack of privacy during the interview. We expected results from the sub-sample to be farther away from the null compared to results from the full sample. The opposite seems to be true. These estimates stem from the fact that 63.2% of older women (the largest users of permanent methods) did not conduct the DHS interview in private. Once this group was excluded from the sensitivity analysis, the significant association between permanent method use and total
fertility rate disappears. The lack of a stronger association between FP methods and total fertility rate in the sub-sample suggest that reduced privacy during the DHS interview is not a concern.
Table 7.9 Average causal effect of family planning methods on fertility, for the sample's subgroup where privacy was enforced during the DHS interview

<table>
<thead>
<tr>
<th>Between Regions</th>
<th>Total Fertility Rate</th>
<th>ACE</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oral contraceptives</td>
<td></td>
<td>-1.03</td>
<td>(-2.40, 0.34)</td>
</tr>
<tr>
<td>Injectable contraceptives</td>
<td></td>
<td>-0.13</td>
<td>(-0.89, 0.65)</td>
</tr>
<tr>
<td>Barrier methods</td>
<td></td>
<td>-0.43</td>
<td>(-1.54, 0.61)</td>
</tr>
<tr>
<td>Permanent methods</td>
<td></td>
<td>-0.90</td>
<td>(-2.23, 0.41)</td>
</tr>
<tr>
<td>Traditional methods</td>
<td></td>
<td>0.73</td>
<td>(-0.65, 2.23)</td>
</tr>
</tbody>
</table>
Under-five mortality: In a replication of the under-five mortality rate model described for Specific Aim 1, the model compares regions exposed to an FP method to regions that are not exposed. Estimates of ACE values of FP methods on under-five mortality rate measures are reported in Table 7.10. This rate is higher in regions exposed to any of the FP methods compared to that of non-exposed regions – with the exception of traditional methods. However, none of these differences reach statistical significance. Therefore, for each FP method under consideration, there seems to be no statistically significant difference between exposed and non-exposed regions on their under-five mortality rates.

In the corresponding ACE values of Aim 1, where the full sample was employed, none of the FP methods considered reached significance as well. This result does not support the hypothesis that the DHS data incorporates social desirability bias due to lack of privacy during the interview. As with fertility estimates, we expected results from the sub-sample to be farther away from the null compared to results from the full sample. The opposite seems to be true. The lack of a stronger association between FP methods and under-five mortality rate in the sub-sample suggest that reduced privacy during the DHS interview is not a concern.
Table 7.10 Average causal effect of family planning methods on under-five mortality, for the sample's subgroup where privacy was enforced during the DHS interview

<table>
<thead>
<tr>
<th>Method</th>
<th>ACE</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oral contraceptives</td>
<td>1.63</td>
<td>(-24.39, 28.78)</td>
</tr>
<tr>
<td>Injectable contraceptives</td>
<td>1.49</td>
<td>(-15.09, 18.28)</td>
</tr>
<tr>
<td>Barrier methods</td>
<td>9.79</td>
<td>(-18.09, 36.59)</td>
</tr>
<tr>
<td>Permanent methods</td>
<td>9.80</td>
<td>(-41.06, 61.24)</td>
</tr>
<tr>
<td>Traditional methods</td>
<td>-13.11</td>
<td>(-60.22, 32.31)</td>
</tr>
</tbody>
</table>
7.6 Summary

To summarize, this chapter reported a description of the DHS sample employed for this dissertation, along with the distribution of both the exposure and the outcomes of interest across levels of maternal age and region of residence. We answered Aim 1: we expect permanent FP methods to significantly reduce the total fertility rate of regions that employ this strategy. Conversely, we do not expect any of the FP methods considered to significantly reduce the under-five mortality rate. We also test different regional context descriptions to assess the importance of this model specification on the associations of interest. We answered Aim 2: we expect oral contraceptives to impact population projections from 2010 to 2025 the most. We also expect barrier methods to impact these projections to least. Finally, we found no evidence of social desirability bias in data collected during the DHS interviews, regardless of privacy status.
8. Discussion

8.1 Overview

The research question this dissertation addresses is whether a woman's fertility would change if 1) the type of family planning (FP) method used; and 2) the prevalence of use were to vary under alternate social and environmental conditions. This chapter summarizes the findings described in Section 7, places them within the context of the Tanzanian contraceptive literature, describes the strengths and limitations of this dissertation, and presents some recommendations for future research and policy strategies.

8.2 Summary of findings

Specific Aim 1 of this dissertation assesses the independent effect of each FP method on the total fertility rate and under-five mortality rate for regions of Tanzania. The objective is to identify the FP methods that most effectively curb a region's fertility and under-five mortality. Permanent FP methods (i.e., male and female sterilization, intrauterine devices, and implants) are expected to reduce the total fertility rate of exposed regions, compared to non-exposed regions. We re-estimate the same association under two additional regional context definitions to assess whether changes in the model specifications result in changes in the estimates. Estimates did vary according to the regional context description used. Hence, different specifications of the regional context can affect the association between FP methods and fertility outcomes.

We repeat this analysis – comparison between regions, followed by individual-level comparisons to test two additional regional context specifications – with under-five
mortality as the outcome of interest. Regardless of model specification, none of the contraceptives considered seem to reduce the under-five mortality rate of exposed regions compared to non-exposed. Different specifications of the regional context do not seem to impact the association of interest.

Specific Aim 2 re-calculates Tanzania's population projections (from 2010 up to 2025) for different proportions of each FP method's use. The objective is to assess the prevalence of each FP method that would be necessary to reduce the country's population growth trends. The FP method that is expected to curb the number of both fertility and under-five mortality events the most is oral contraceptives. The FP method that is expected to curb fertility the least is barrier methods, while under-five mortality is affected the least by traditional methods. Next, we re-estimated population projections between 2010 and 2025. Again, the FP method expected to curb population growth the most is oral contraceptives. This FP method seems to be the only one where an increase in prevalence would produce a decline in population growth. Conversely, the FP method expected to curb population growth the least is barrier methods.

Finally, we conduct a sensitivity analysis to assess the presence and magnitude of social desirability bias in answers to the contraceptive items of the 2010 Tanzania Demographics and Health Survey (DHS). Contraceptive use is often frowned upon by relatives who prize high parity. Respondents may not be able to answer contraceptive questions truthfully if another person is present. We expected results to show a stronger association between FP methods and the outcomes, since more women admit to FP use. Instead, social desirability bias impacts respondents' answers to a very small degree.
None of the contraceptives considered seem to reduce total fertility rate of exposed regions, compared to non-exposed regions. The same scenario presents itself when the outcome of interest is under-five mortality events.

8.3 Specific Aim 1

8.3.1 Current literature

This study considers how the contextual effects created by regional characteristics engender differential access to contraceptive resources, and consequentially differential fertility outcomes. We could find no studies in the literature that addressed this issue through a randomized experiment. Therefore, we cannot compare our results with those generated by a trial. Instead, we use observational studies to assess which methods are considered to be most effective in the Tanzanian context. None of the studies reviewed compares FP methods to one another to assess their different effectiveness in preventing fertility and under-five mortality events. Rather, each examines the effectiveness and acceptability of one or two contraceptive methods, or of all modern methods combined. The context in which choices take place is seldom taken into account (Stephenson et al., 2007). In most instances, respondents characteristics are collected, but are only used to adjust regression models (Hubacher et al., 2008; Ngure et al, 2012; Wickstrom et al., 2008; Plummer et al., 2010; Tengia-Kessy et al., 2006; Sutherland et al., 2012; Hollos et al., 2003). Furthermore, those few studies that compare FP methods have as their outcome the prevalence of method use (Tengia-Kessy et al., 2006; Sutherland et al., 2012) or the incidence of pregnancy (Ngure et al, 2012), but make no mention of independent treatment effects. This suggests that the data have not been pre-processed to
better balance confounders across exposure groups. Therefore, no claims to causal inference can be made. Finally, only two of these studies are specific to Tanzania (Tengia-Kessy et al., 2006; Hollos et al., 2003). All others consider more than one African country.

8.3.2 Fertility

We expect permanent contraceptive methods to reduce the total fertility rate of exposed regions by the widest margin. Given these limitations in the literature, it is difficult to compare this result to those reported elsewhere. Nonetheless, studies that assess the effectiveness of permanent contraceptive methods confirm that this strategy is the most effective in curbing a woman's number of births after she becomes a user (Wickstrom et al., 2008; Ngure et al, 2012; Hollos et al., 2003). These effects easily translate to the regional level. We expect the total fertility rate to be most impacted by permanent methods. This finding is not surprising. Unlike other FP strategies, the effectiveness of this method is 100% (Stover et al., 2005). Importantly, it requires a single application (in the case of surgical sterilization) or very few visits to the clinic (in the case of implants and intra-uterine devices) – thus making discontinuation highly unlikely. Once a woman becomes a user, she is no longer at risk of pregnancy. It is reasonable to expect regions exposed to this method to have a significantly lower total fertility rate compared to non-exposed regions.

We do not expect any of the other FP methods to significantly impact the total fertility rate of exposed regions. Some of these methods have low effectiveness. For example, traditional methods have 50% effectiveness (Stover et al., 2005). We do not
expect them to significantly reduce fertility levels in the region. Indeed, one study confirmed our findings by reporting that traditional methods increased the number of pregnancies among users, compared to non-users (Ijaiya et al., 2009). While the use of traditional methods is dropping across Africa (Seiber et al., 2007), their prevalence of use in Tanzania is still high enough to warrant concern (Sullivan et al., 2006).

Barrier methods also have low effectiveness (81%), although not as low as traditional methods. This is due to frequent incorrect use (Stover et al., 2005). Beyond effectiveness, issues, barrier methods also suffer from low consistent use (Exavery et al., 2011; Genberg et al., 2008; Plummer et al., 2006). In the DHS sample, almost all condom users report using a condom at last intercourse. However, we have no information on respondents' condom use before then. Furthermore, condom use is fraught with stigma given its association with HIV. Frequent stock-outs and fear of side effects create additional obstacles to consistent condom use (Plummer et al, 2010). We do not expect this method to significantly reduce the total fertility rate of a region.

Injectable contraceptives reportedly have 100% effectiveness (Stover et al., 2005). However, they are subjected to possible discontinuation due to stock-outs, side effects, or simply the inability of women to reach a clinic every three months. Continuous coverage cannot be assumed. Given these constraints, we do not expect this method to significantly reduce the total fertility rate of exposed regions. For injectable contraceptives to be truly as efficacious as reported in clinical trials, access programs needs to keep this method in stock, train more providers, and find ways to offer it in rural and isolated areas (Richey et al., 2006; Sutherland et al., 2012).
Oral contraceptives are reported to have 92% effectiveness (Stover et al., 2005), so they are considered acceptable alternatives to injectable contraceptives in terms of effectiveness and advocacy (Ngure et al, 2012). They are preferred by younger married women who want to space rather than limit their number of pregnancies (Marchant et al., 2004). Users of this method suffer from the same limitations as the users of injectable contraceptives: namely, stock-outs, side effects, and logistical difficulties in regularly attending a clinic. In addition, oral contraceptives require daily doses – making its users more liable to be discovered by disapproving relatives. Also, each prescription needs to be re-filled every 30 days, requiring monthly trips to the clinic. We are not surprised by this method's lack of effectiveness in reducing the total fertility rate of exposed regions. For oral contraceptives to be truly effective in preventing pregnancies, the same ideal conditions as for injectable contraceptives apply (i.e., keep this method in stock, train more providers, and offer it in rural areas).

8.3.3 Under-five mortality

The literature on the effects of contraceptives on under-five mortality is scarce. Numerous studies link under-five mortality with limited spacing between pregnancies. The risk of child mortality decreases with increasing birth interval length, even for periods of 48 months or more (Rafalimanana et al., 2000; Yeakley et al., 2009; Rutstein et al., 2005; Norton et al., 2005; Justesen et al., 2000; Handa et al., 2010; Tottrup et al., 2009). Birth spacing is directly related to use of contraceptives. Indeed, it is the main reason why most women in Tanzania opt to use an FP method in the first place. However, we could find only one study that specifically observes the association between under-
five mortality and contraceptive use (Rafalimanana et al., 2000). For Tanzania, the under-five mortality rate would be reduced by an estimated 3.3% if women's preferred birth intervals prevailed. The study follows by stating that women who know, approve of, discuss, and use FP prefer longer intervals than do their counterparts. Therefore, women in a position to choose the length of a birth interval through contraceptives would contribute to a reduction in the under-five mortality rate of their region. However, this study does not differentiate between FP methods, so it is difficult to compare our results to those reported in the literature. Nonetheless, the proportion reported is acknowledged to be modest. This result agrees with the estimates we report: namely, that none of the FP methods under consideration is expected to significantly reduce the under-five mortality rate of exposed regions, compared to non-exposed regions.

This null result has two possible explanations. First, our models consider the regional context in which FP method choices are made. In other words, we already account for the country-wide downwards trend in under-five mortality that is currently underway (Masanja et al., 2008; Garenne et al., 2008). Then, the effect of each FP method on under-five mortality is comparatively small, and would result in the null estimate we report. The second explanation posits that the null result stems from our inability to capture all environmental, social, and individual factors that influence under-five mortality. While pregnancy spacing is a critical component in a child's risk of death in Tanzania, it is not the only one. Two studies – one located in Tanzania and one focusing on East Africa – report that child mortality trends have a spatial component that can be attributed to broad-scale environmental and social-economic factors. Individual- and
household-level variables alone seem to lack explanatory power (Tottrup et al., 2009; Handa et al., 2010). While we account for the environmental component that influences FP choice and prevalence, we omit additional individual- and household-level factors that might influence under-five mortality after birth, such as infectious diseases and malnutrition (UNICEF, 2001). The inclusion of such post-birth factors in the analysis, however, is beyond the scope of this dissertation.

8.4 Specific Aim 2

8.4.1 Current literature

Currently, the population of Tanzania counts approximately 39 million individuals. However, United Nations projections place the size of country's population between 120 and 150 million by 2050 (UN, 2010). The Tanzania National Bureau of Statistics (NBS), instead, estimates that the country's population will swell to approximately 65 million by 2025 (NBS, 2002). Clearly, the population of Tanzania is growing exponentially. Scarce resources will be stretched even farther unless drastic changes in population control occur soon. Voluntary family planning is the most efficient solution from both a development and a monetary perspective. It allows women to space pregnancies farther apart, to improve the welfare of their children, and to participate more actively in education and labor activities (Larsen et al., 2003; Kravdal, 2001). From a monetary point of view, FP is the most cost-effective strategy to boost household economics by focusing resources on fewer children (Singh et al., 2009).

The population projections estimates thus far do not take into account the possibility of increasing the prevalence of different contraceptive method. We re-estimate
population projections under different FP scenarios to assess how the size of the country changes if varying proportions of different contraceptive methods were reported. The most dramatic difference occurs when the prevalence of oral contraceptive use is expected to increase. The number of births in the previous 36 months is expected to decline from 6,295,744 (current prevalence of use) to 1,454,033 (if prevalence of use were increased by 19%, thus eliminating reported unmet need for contraceptives). The number of under-five deaths in the previous 60 months among oral contraceptive users is expected to decrease from 256,573 to 49,496 when prevalence in increased by 19%.

Instead, when the prevalence of barrier methods' use is increased, the predicted population size increases as well. The number of births in the previous 36 months is expected to increase from 5,906,008 (current prevalence of use) to 13,385,664 (if prevalence of use were increased by 19%). The number of under-five deaths in the previous 60 months for this group of FP users is expected to increase from 256,564 (current prevalence of use) to 355,248 (if prevalence of use were increased by 19%).

Population projections reflect these trends. In 2025, the projected population of Tanzania would be 32,878,855 if oral contraceptive prevalence of use increased by 19%. This is a dramatic decrease from the 65 million figure projected by NBS for 2025. Conversely, the projected population of Tanzania in 2025 would be 81,496,280 if barrier methods' prevalence increased by 19%. This is an equally dramatic change in population size, albeit in the opposite direction.

Previous studies that estimate the effects of FP on population growth either consider the whole of Africa together, do not account for varying proportions of FP use, or do not
differentiate between FP methods (Ezeh et al., 2009; Westoff, 2006; Singh et al., 2009). Therefore, it is difficult to compare previous estimates with our results. Nonetheless, all studies report considerable reductions in the number of births when all unmet need for FP is fulfilled. Singh et al. (2009) state that the number of childhood deaths would greatly decrease if modern contraceptives were universally used.

### 8.4.2 Oral contraceptives

In all models designed to answer Specific Aim 2, oral contraceptives emerge as the most promising FP method to curb the number of births and under-five deaths. It also is the contraceptive strategy most likely to reduce the population growth trend experienced by Tanzania. When prevalence is increased by 19%, population size starts to decline by 2025. None of the other FP methods is expected to produce this result.

The finding that oral contraceptives are the most effective FP method is somewhat surprising. Based on findings from the literature, injectable contraceptives would seem the most likely candidate for population reduction. Compared to oral contraceptives, we expected the injectable method to be the most successful in the prediction models. They have a reported effectiveness of 100%, while that of oral contraceptives is only 92% (Stover et al., 2005). These measures of effectiveness assume that the method has been taken as directed and that adherence is complete. However, these assumptions do not consider the frequent stock-outs (especially in more rural communities), the impossibility to attend clinics when necessary because of distance or family obligations, and the secrecy that surrounds FP use in the first place. Even when accounting for these conditions, injectable contraceptives should be the more effective method because they
require a single dose every three months, while oral contraceptives are sold in 30-day supplies. Hence, the possibility of poor adherence is higher with oral contraceptives than with injectable contraceptives. The frequency of prescriptions refill is higher for oral contraceptives, and they must be taken every day rather than in one dose. Furthermore, injectable contraceptive use is easier to disguise because there are few external signs. Finally, the prevalence of injectable contraceptive use is higher in this sample compared to the prevalence of oral contraceptives.

Despite the advantages of injectable contraceptives, we expect oral contraceptives to be the most effective FP method in reducing the number of births and under-five mortality events, and to curb population growth the most. The reason may be found in the consistency of oral contraceptive use across age groups. As shown in Figure 8.1, oral contraceptive use is set at 20% across the four age groups that are most fertile (i.e., women in their twenties and thirties). Injectable contraceptive use, instead, is concentrated among women in their twenties (especially the 25 to 29 age group), but declines rapidly among older women.
Figure 8.1 Proportion of oral vs. injectable contraceptive users, by maternal age group
As shown in Figure 7.1 of Section 7, however, women in their thirties are still bearing a considerable proportion of the children in the population. Therefore, women who were injectable contraceptive users in their twenties may forgo protection in their thirties, but are still at high risk for pregnancy. Instead, women who were oral contraceptive users in their twenties continue to be users in their thirties, thus remaining protected against pregnancy. This interpretation is supported by Figures 7.3a and 7.3b in Section 7. In Figure 7.3a (oral contraceptives), births and under-five deaths fall dramatically in the four most fertile age groups (ages 20 to 39) as prevalence of use increases. Conversely, Figure 7.3b (injectable contraceptives) show that the most dramatic reductions in births and under-five deaths occur among women age 20 to 29. Women in the 30 to 39 age groups, instead, are expected to have a much smaller reduction in births and under-five mortality events, despite the same increase in prevalence of use. Therefore, we posit that the consistent use of oral injectables across the most fertile years has a stronger effect in reducing the population's fertility and under-five mortality trends compared to the shorter use of the more effective strategy of injectable contraceptives.

**8.4.3 Barrier methods**

We obtained puzzling results for respondents who use barrier methods as their primary contraceptive strategy. The number of fertility events increases as prevalence of use increases. These trends carry over in the population projection calculations. For all other modern methods, the number of events decreases when prevalence of use increases – as expected.
One possible explanation is that these trends reflect poor consistent condom use rather than poor method effectiveness. To verify this hypothesis, we first reviewed the exact wording of the item in the DHS questionnaire. It asks: "Which method are you using?". The instructions manual specifies that the interviewer should ask about the "current use of contraception", which cover "the most recent acts of intercourse" (DHS, 2012). However, unlike the other methods, condoms are a coitus-based method: they need to be used at every instance of intercourse to prevent pregnancy in the long run. If the respondent used a condom at last intercourse, she would be recorded as a current FP user. However, we have no information on her long-term protection against pregnancy. The distribution reported for condom users may result from women using condoms sporadically and still being counted as current users because they used a condom at last intercourse. It would be no surprise, then, to see that their fertility distribution resembles that for traditional methods' users.

Next, we reviewed the available data to exclude competing explanations. First, we looked for other modern coitus-based methods (e.g., diaphragm) to assess whether their distributions acted similarly to that of condoms. However, answers in the DHS data do not include any other modern coitus-based method, so we cannot assess whether a similarity exists. Second, we considered whether condom users are also using another FP method at the same time. Possibly, users employ condoms against HIV infection and rely on another contraceptive method to prevent pregnancy. However, out of the 431 women who report condoms as their current contraceptive method, only 10 also use another method for family planning. Third, we try to estimate the proportion of condom use over
all the sex acts performed in a previous period. However, DHS only records whether a
woman used a condom at last intercourse. Numerous studies in both the contraceptive
and HIV literature employ this measure of condom use, and derive their statements on
poor consistent use from this variable (Walque et al., 2011; Exavery et al., 2001;
Plummer et al., 2010). However, this information assumes that a respondent's behavior at
last intercourse is reflective of her behavior at each instance of intercourse (Curtis et al.,
2004). A better measure of consistent condom use would calculate the number of
condom-protected sex acts over the number of sex acts during a specific period of time.
We could find only one study in Tanzania that estimates consistent condom use this way.
It reported that only 5.6% of women (married or unmarried) "always" used condoms in
the previous 6 months (over an average eight sex acts per month), while 17.5% use
condoms "sometimes". No mention was made to concurrent contraceptive methods
(Genberg et al., 2008). A second study, set in Uganda, reported that only 36% of
respondents in a representative sample of adolescent women engaged in consistent
condom use, defined as use at each act of intercourse in the previous three months
(Bankole et al., 2007). Furthermore, one study from the HIV literature states that: "For
women, condom use was a highly significant predictor of HIV status and of HIV
infection in the interval prior to the survey". Therefore, it seems that condom use can be
construed as a proxy measure for a whole host of high-risk behaviors (e.g., multiple
partners, partner's infidelity, desire for high parity, etc.) rather than a protective measure
against pregnancy or sexually transmitted diseases. Therefore, the fertility distributions of
condom users – as well as the population projection for this group – likely reflect the
effects of inconsistent condom use on population growth.

8.5 Sensitivity analysis

In Section 6.7, we hypothesized that the DHS data include social desirability bias. We base this hypothesis on the information we collected from the focus groups in Tanzanian villages during the 2010 summer months. During these conversations, women reported that they would be more likely to under-report their true frequency of FP use if another person were in the room.

The DHS documentation recognizes this limitation. The interviewer manual recommends that this section be completed in private so the respondent does not feel embarrassed (DSH, 2010). This strategy prevents respondents from giving only socially acceptable answers (Haws et al., 2010). Privacy, however, may be difficult to achieve in this setting. Respondents' dwellings tend to be small and crowded, so there is little space for a private conversation. The possibility of being overhear is high. Contraceptive use is often stigmatized by older relatives who prize high parity and fear many of the side effects associated with FP use (Plummer et al., 2010). Numerous topics face such restrictions in this setting, so it is not surprising that respondents' answers be limited to a small circle of acceptable options (Haws et al., 2010; Curtis et al., 2004; Kidolezi et al., 2009; Plummer et al., 2010). Hence, respondents may under-report their use of contraceptives to make their answers more acceptable to older relatives.

However, our results seem to reject this hypothesis. Among the sub-sample of respondents who were guaranteed confidentiality, we expected estimates to be farther away from the null compared to estimates from the full sample. Instead, we obtained null
results on all FP methods considered for both total fertility rate and under-five mortality rate. As stated before, the results reported for Specific Aim 1 lead us to expect a reduction in both the total fertility and the under-five mortality rate for regions exposed to permanent methods, compared to non-exposed regions.

The distribution of private interviews across age groups offers some explanation for these null results. One third of women in the 44-49 age group and one quarter of women in the 40-44 age group were not administered the DHS interview in private. Approximately 42% of permanent method users fall in these age groups. Hence, these women were eliminated from the sub-sample analysis, thus rendering null the previously statistically significant result for this FP method. However, there is no difference between the prevalence of permanent method use reported in the full sample and in the sub-sample. One possible explanation is that older women occupy a prominent position in the household, and therefore are not subjected to stigma if they admit to FP use in the presence of others. A second explanation is that the use of permanent methods is very difficult to hide, if only because it requires professional medical assistance and, in the case of sterilization, surgery. Therefore, it is likely that family members are aware that the woman had the procedure. There is no need to conceal the fact from others. Indeed, 5% of women admitted using permanent methods in both the sample and the sub-sample (see Table 7.8 in Section 7).

Younger women, instead, do not have the same power as their older female relatives. They must be careful to avoid admitting to a stigmatized behavior like FP use. Yet they are the highest users of oral and injectable contraceptives, barrier methods, and traditional
methods. The combination of FP use and lower rank within the household is reflected in the data. Except for barrier methods, all other methods are reported in higher proportions in the sub-sample compared to the full sample. The reported use of any FP method also is higher in the sub-sample compared to the full sample (69% vs. 71%) Of particular interest is injectable contraceptive use. While in the full sample the prevalence of use is 8%, it is 10% in the sub-sample. This method is used by younger women who want to space or limit pregnancies (Sutherland et al., 2012). The use of this method is also very easy to conceal, because it requires a single injection every three months (Ashford et al., 2008). Therefore, it likely is the preferred method of women who wish to keep their FP strategies secret. It is not surprising, then, that more women admit to its use in private.

However, private interviews do not seem to elicit significantly more admissions of FP use. Indeed, we do not expect any difference in births and under-five deaths among exposed regions. Two explanations are possible. First, FP users may insist on confidentiality when interviewed. While privacy inside the house is unlikely, the interview may be conducted outside away from a third party. Respondents can give more honest answers to FP items in the interview. Second, respondents underreport their use of FP methods, regardless of the presence of a third party. The sensitivity of these items may be great enough that admitting use to anyone – even a trained professional with guarantees of confidentiality – is difficult.

Given these results, we posit that there is some evidence of social desirability bias – as evidenced by the greater proportion of use reported for injectable contraceptives, oral contraceptives, and barrier methods in the sub-sample. However, this increase in the
reported proportion of use does not lead to more extreme average causal effect values (as initially hypothesized). We conclude that social desirability bias is incorporated in the DHS contraceptive data, but not to a degree that warrants concern.

8.6 Hypothetical counterfactuals

In Section 6.2, we describe the hypothetical counterfactual scenario, where observations in the control group are composed of contraceptive non-users as well as users of any method different from the one under observation. This configuration affects the interpretation of the results. From an epidemiology point of view, the composition of the control group is problematic because it does not allow researchers to compare the effectiveness of each contraceptive method against a true null control. In our hypothetical experiments, the inclusion of users of other methods in the control group assumes that their effect on fertility and under-five mortality is nil. Instead, previous studies show that each other method has some effect in reducing these outcomes – with the possible exception of barrier methods and traditional methods (Walque et al., 2011; Exavery et al., 2001; Ijaiya et al., 2009; Sullivan et al., 2006). Therefore, by comparing users of one method to non-users and users of all other methods, we bias the estimates toward the null. This occurs because we hypothesize a null control, but in reality use a control group that impacts the outcomes of interest. The exposed and non-exposed groups are more similar to one another than they should be. As a result, the specific FP method appears to be less effective in reducing TFR and under-five mortality rate than it would be when compared to a true null control. Population projections for incremental prevalence of each FP methods also would underestimate the effectiveness of each contraceptive in mitigating
growing population trends. However, the proportion of non-users in the sample far outweighs that of users of any method (71% and 29%, respectively). Most of the control arm is made up of observations in the former group. Therefore, we posit that the bias due to inclusion of all other FP method users in the control group does not generate a strong type II error.

From a policy point of view, the composition of the control group is problematic because it does not allow for clear recommendations. By increasing the prevalence of use of one contraceptive, we decrease the proportion of non-users as well as the proportion of users of all other methods. It is unclear, then, which of these two sub-groups to target. Should precedence be given to non-users, so that they adopt any contraceptive method? Or should precedence be given to users of less effective methods, so they increase their probability of limiting the number of reproductive events? Previous studies recommend that users of modern methods should not be asked to switch to another method if they have no issues with the current one. The unprotected period between contraceptives would put them at higher risk of pregnancy (Cleland et al., 2010). Also, we want to avoid promoting one method that may meet resistance from the community, to the detriment of another that may not be as effective but is well accepted. Instead, interventions should target non-users, and encourage them to adopt the most effective methods (i.e., oral and injectable contraceptives). Limited resources can be focused on new users and targeted towards the adoption of the most effective methods. In the meantime, users of other modern methods can continue to be protected by the contraceptive of their choice.
These considerations are particularly important when interventions include Muslim women, whose faith strongly prohibits the use of contraceptive methods – more than for Christian women (Agadjanian et al., 2009). The concern is that no intervention or incentive can overcome religious tenets, and that Muslim women will never become contraceptive users. The 2010 iteration of the DHS does not include information on religion, so it is difficult to assess whether there is an association between a respondent's religious affiliation and her contraceptive use. However, the 2004 iteration of the DHS does release this information. Therefore, we calculate the prevalence of Muslim women in each region, assuming that the religious composition of a region does not change dramatically between 2004 and 2010. For each region, we juxtapose the proportion of Muslim women to the proportion of contraceptive non-users (calculated from the 2010 DHS). The only regions where there is overlap between high proportion of Muslims and high proportion of non-users are the islands of Pemba and Zanzibar. All other regions show no overlap. For example, 75% of women in the Tanga region are Muslims, but non-users constitute only 55% of inhabitants. Conversely, only 5% of women in the Shinyanga region are Muslims, but non-users constitute 87% of inhabitants. Therefore, belonging to the Islamic faith does not seem to be a strong determinant of contraceptive non-use. Exceptions are the islands of Zanzibar and Pemba – where the proportion of Muslim women ranges from 95% to 100%. It seems that a more homogeneous religious environment engenders a stronger the opposition to contraceptive use (Agadjanian et al., 2009). Interventions targeting Muslim non-users – as opposed to Christian non-users – in
religiously mixed regions should tailor their interventions to account for religious concerns, but should not assume that stronger doses are needed to impact FP behaviors.

8.7 Strengths and limitations

8.7.1 Limitations

The most serious limitation of this dissertation is its use of cross-sectional data, and therefore the impossibility of accounting for temporality. Contraceptive use always antecedes fertility and under-five mortality events, if only because respondents are using FP to avoid these events in the first place. However, in the DHS datasets, contraceptive use and the fertility and mortality outcomes are measured at the same time. Unfortunately, we could not find a longitudinal dataset that matched the DHS in scope, detail, quality, and geographical coverage. Given the data available, it is not possible to establish on an individual basis whether the current FP method used (if any) influences the most recent birth and under-five death events. Regional estimates, instead, relax the temporality requirement by assessing the association between prevalence measures of each contraceptive method and regional estimates of fertility and under-five mortality. When using estimates aggregated at the regional level, however, we fail to measure some of the association's strength because individual effects are averaged across the region. Results likely underestimate the true effect of each FP method on fertility and under-five mortality. Statistically significant results should stand out even more strongly given this set-up.

A second limitation is the difficulty of defining the regional context in which FP choices take place. It is impossible to completely capture what constitutes an
environment in which health decisions are made. Too many time-varying parameters affect its composition, and not all of them can be accurately captured through quantitative data (Sampson, 2011). We must rely on a few measurable variables that capture the salient characteristics of a context, given the research question at hand. Therefore, we defined the regional context for this dissertation based on information on the region of residence (Hollos et al., 2004), the respondent's educational attainment (Hollos et al., 2004; Kravdal, 2001; Larsen et al., 2003; Marchant et al., 2004; Vavrus et al., 2003), her household wealth (Cleland et al., 2006; Khan et al., 2006), and her urban/rural status (Chen et al., 2003, Arends-Kuenning et al., 2007). While these are only a few of the characteristics that define an environment, they are widely discussed in the Tanzanian contraceptive literature as strongly associated with FP use. We believe they shape the environment in which a contraceptive user lives, and therefore constitute the regional context in which FP choices are made. While these four variables certainly do not form a complete picture of a respondent's environment, they allow for a satisfactory definition of it. We use it to account for the regional context in all our analyses.

A third limitation is the lack of great geographical detail in the DHS dataset. The data only contain regional demarcations, and therefore do not allow us to define the social context beyond the regional level. Tanzania is a very diverse country: ethnic, social, and linguistic differences do not always follow regional boundaries (Lawrence, 2010). Therefore, we do not capture some of the social variation within each region. However, rather than foregoing accounting for the regional context in its entirety, we prefer a
coarser demarcation system that allows us to incorporate some of the effects of location in our estimates.

A final limitation concerns data collected around condom use. The DHS only collects information on condom use at last intercourse (DHS, 2010). As mentioned above, this information assumes that a respondent's behavior at last intercourse is reflective of her behavior at each instance of intercourse. This assumption is often refuted when prospective data are examined (Genberg et al., 2008). For this dissertation, we can only assess whether a respondent is currently using (i.e., at last intercourse) condoms as a contraceptive method. This information offers us no insight on the consistency of her FP use. We cannot make strong statements on the efficacy of condoms in preventing birth and under-five death events in the long run.

8.7.2 Strengths

The main strength of this dissertation is the use of an experimental design framework while employing observational data. Interventions when women are randomized to one FP method versus another require considerable follow-up time and resources, especially in Tanzania where infrastructures are scarce. Observational data allow us to estimate the association between contraceptives and fertility or under-five mortality events. Often, however, they adjust the association for region-level characteristics by simply including these variables in the regression model. This dissertation, instead, pre-processes the data so that observations may be matched with suitable counterfactual substitutes. The resulting estimates reflect less model dependence, lower bias, reduced homogeneity, and increased efficiency (Ho et al., 2007; Iacus et al., 2008).
A second strength is the differentiation between contraceptive methods to estimate the effect of each on fertility and under-five mortality. Most studies prefer to treat all modern FP methods as undistinguishable in their impact (Ezeh et al., 2009; Singh et al., 2009; Hollos et al., 2003). The few that do consider each method independently cover vast geographical areas, like Sub-Saharan Africa, and do not consider the effect of each method within specific contexts (Ijayia et al., 2009; Hubacher et al., 2008). Alternatively, they consider each method individually, and do not compare its effectiveness to that of other contraceptive methods (Richey et al., 2006; Sutherland et al., 2012; Wickstrom et al., 2008; Plummer et al., 2010). Nonetheless, each method impacts different groups of women differently, if only because of their age and limitations specific to their environment. This dissertation adds to the contraceptive literature by focusing specifically on Tanzania and by considering the effect of each FP method independently, so that policy recommendations can be specific and targeted.

A third strength is the consideration of different definitions of the regional context. In Specific Aim 1 we assess the associations of interest by comparing regions, women within regions, and women across the country. We toggle between model specifications, and compare estimates under different regional conditions. We could not find in the contraceptive literature other studies that considered the regional context under different model specifications, or that compared the estimates from these specifications.

A fourth strength is the passage from an individual-level association between FP methods and fertility or under-five mortality to country-level estimates of population growth under different FP scenarios. Coleman (1990) states that, in order to assess any
changes at the population level, we must first understand the mechanisms of change at
the individual level. While multiple studies assess the impact of societal characteristics
on individual-level outcomes (Ezeh et al., 2009; Stephenson et al., 2007), we found very
few studies where individual-level outcomes were translated back to the population level
estimates (Westoff, 2006; DHS, 2010). None of them focuses on the population growth
trends of a specific country. Specific Aim 2 of this dissertation, instead, presents exact
estimates of population projections for Tanzania using varying estimates of individual-
level FP use.

The final strength of this dissertation is the use of a sensitivity analysis to assess the
presence of social desirability bias in the DHS data. Previous studies suggest that
contraceptive use under-reporting is very likely in Tanzania, given strong disapproval
from older relatives (Mulder, 2009). The 2010 DHS data also report that about one third
of interviews may not have been conducted in private. Therefore, the possibility of social
desirability bias is strong. The sensitivity analysis we conducted allows us to confirm the
presence of this bias in the data, and interpret results accordingly.

8.8 Recommendations

8.8.1 Future research

The results of this dissertation suggest future avenues of research for the field of
contraception use in Tanzania. First, we recommend that the experimental framework be
used more explicitly when using observational data. The random allocation of women to
different FP methods across the country is a very complex design, and one that is nearly
impossible to implement in a country where basic infrastructures and health services are
subpar (Marchant et al., 2004). Observational studies are the best strategy to obtain information on the associations of interest. Yet, the application of an experimental framework allows us to draw some causal inference, even in the absence of a randomized trial. In this study, the experimental design was applied through matching regions on potential confounders. Pre-processing on all potential confounders in the absence of perfect matching cannot replicate the counterfactual ideal. However, it allows us balance the strongest confounders across condition arms. The resulting estimates gain in precision without requiring additional complex analytical tools.

Second, the literature on contraceptive use would benefit from greater focus on individual countries, rather than calculating summary estimates from the entire Sub-Saharan African region. While these summary reports offer an overview of the current situation, they gloss over the vast cultural and linguistic differences that exist both within and between countries. As this dissertation shows, the context in which FP users live greatly influences their contraceptive choices, and therefore their reproductive outcomes. Future interventions on contraceptive uptake and continued use must take into consideration the specific characteristics of the environment in which women live. Without baseline estimates specific to the country, these interventions will likely be generalized and ineffective. By the same token, greater specificity is warranted when examining the type of FP method used. A generic discussion of modern FP methods overlooks the differences that exist in each method's effectiveness, prevalence of use across age groups and socio-economic status, and local availability. Future interventions will benefit from this additional tailoring in both targeting and content.
Finally, a sensitivity analysis helps uncover potential biases in the dataset. Even data with a reputation as solid as those from the DHS are not above concern, given the standardized nature of this cross-country effort. Qualitative investigations carried out in-country (such as the focus groups discussed in Section 5) can suggest where the potential biases lie. Yet there are few instances in the literature where researchers toggle between different sample and model specifications to test their effect on the estimates (Hubacher et al., 2008). Readers are left wondering whether the estimates reported reflect the true association of interest or are a result of the author's specifications. Sensitivity analyses can help quell such concerns by eliminating competing explanations when interpreting the analysis' results.

8.8.2 Policy implications

Results from this dissertation allow us to make policy recommendations that can impact contraceptive use in Tanzania, and consequently the country's rate of fertility, under-five mortality, and predicted population growth. First, our results suggest that investing in oral contraception promotion can have significant impact on the fertility and under-five mortality events a woman experiences. This seems especially true if the focus is on the consistent and prolonged use of this FP method throughout a woman's twenties and thirties (i.e., her most fertile years). We expect these results to translate in diminished population growth. We also recommend that the same promotion be applied to injectable contraceptives. As described in Section 8.4.2, this method is more effective than oral contraceptives, requires fewer doses, and can be hidden more easily. If its prevalence of
use remained constant throughout a woman's twenties and thirties, it is likely that its effect on population growth would be equal or stronger to that of oral contraceptives.

Of course, we do not recommend that permanent methods and barrier methods be ignored in favor of oral and injectable contraceptives. Some FP users prefer these methods over oral contraceptives because of fewer side effects or longer periods between doses. It would be detrimental to the country's family planning goals to reduce women's options. Instead, we suggest that any additional resources be routed towards increasing the availability of injectable and oral contraceptives among the most fertile age groups, while funding for other modern methods remain at their current levels.

A second policy recommendation is to discourage the use of traditional methods across all age groups. The effectiveness of these methods is reportedly 50% (Stover et al., 2005). As results suggest, fertility and under-five events only increase as the prevalence of use increases. Population growth trends follow suit. However, it may be very difficult to dissuade users to apply these traditional practices. They are usually imparted by older female relatives, whose knowledge is rarely questioned. Also, traditional methods are independent of medical consultations, stock-out, or financial constraints. They can be easily adopted by any woman who wishes to limit or space her pregnancies (Plummer et al., 2010; Ashford et al., 2008). Therefore, intervention programs must promote modern contraceptive methods while discouraging the use of traditional strategies. To be successful, they must be sure to offer viable alternatives that increase protection without increasing pricing. Strong delivery and service infrastructures, coupled with consistent
and comprehensive education, are also necessary to make modern methods a feasible and safe alternative to traditional strategies.

Finally, interventions to promote condom use either against HIV infection or pregnancy should be strengthened so that consistent use increases. At the moment, the HIV literature for Tanzania agrees that consistent condom use is low among young women, and almost non-existent among older or married women (Plummer et al., 2010; Blanc et al., 2009). This is due to a number of factors: the stigma associated with the suspicion of a partner being HIV-positive, the cost of condoms, the frequent stock-outs in rural clinics, and the unnecessary barriers placed by medical personnel on condom distribution (Plummer et al., 2010; Montgomery et al., 2008; Campbell et al., 2006; Speizer et al., 2000). Far less has been said about poor consistent condom use in the contraceptive literature. Nonetheless, these barriers affect a woman's risk of pregnancy just as much as her risk of infection. New interventions are starting to pool resources by uniting the two prevention messages and stressing the advantages of consistent condom use on multiple fronts (Lush et al., 2001; Keogh et al., 2009). Priority (both political and financial) should then be given to consistent messages that recommend condoms as a prevention strategy for both HIV infection and pregnancy.

8.9 Conclusions

In conclusion, the results of this dissertation suggest that permanent FP methods used in 2010 are most effective in reducing total fertility rate and the under-five mortality rate of exposed regions compared to non-exposed regions. This is not surprising, considering that this method is the only one that eliminates the risk of pregnancy once assumed.
When re-estimating population projections for Tanzania between 2010 and 2025, oral contraceptives are the most effective method to curb the number of births and under-five mortality events – and therefore the country's population size. This is likely due to the consistent proportion of use across a woman's most fertile years. The FP method that fares the worse in population reduction is barrier methods, most likely because of the high rate of inconsistent condom use among women. Finally, the sensitivity analysis we run using only data from privately held interviews shows little evidence of social desirability bias in the DHS contraceptive items.
9. Bibliography


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196
Appendix A

Geopolitical map of Tanzania (as of 2012)