Density of Family Planning Service Availability, Kernel Density Estimation of Access to Contraceptives in Malawi

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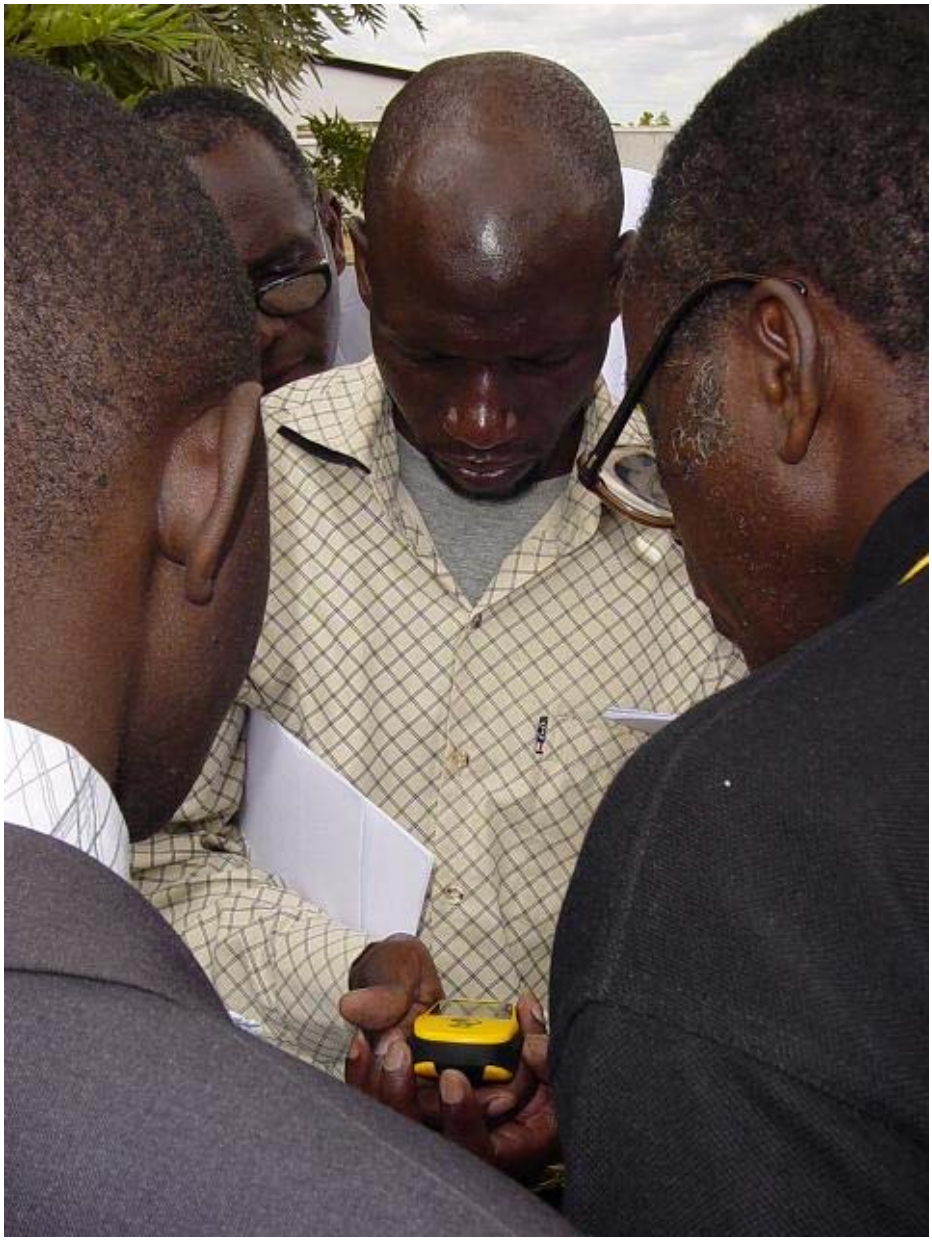

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Abstract

Malawi faces immense reproductive health challenges, many of which could be ameliorated with an increase in contraceptive use. The main objective of this paper is to see if analysis of spatially referenced facility and health data can identify a gradient of access to specific services and determine whether and how the gradient affects the utilization of contraceptive services in Malawi. The methods employed in this paper include one of the first examples of kernel density estimation as a means of identifying the presence and health significance of access to health services. Results show that Malawian women who lived in areas of medium and low density family planning availability were significantly less likely to use modern contraception compared to women who live in high density areas. These results indicate the development of a novel means of identifying disparities in access to family planning services in Malawi and perhaps more broadly in sub-Saharan Africa. The paper makes a broader contribution to the literature on access to health services in sub-Saharan Africa.

Background

Malawi faces immense reproductive health challenges. Maternal mortality is catastrophically high at 1,800 per 100,000 live births (UNDP, 2004). Incomplete abortions account for 42%-72% of acute gynecological admissions in Malawian hospitals (Kinoti et al., 1995). An increase in contraceptive use could reduce morbidity and mortality associated with negative sequelae of pregnancy and birth. However, contraceptive use in Malawi is low. Only 21.5% of married and sexually active unmarried women use some kind of modern contraceptive method (MDHS, 2000).

In a study of maternal mortality in 49 developing countries, Bulatao and Ross found that family planning services are more closely associated with lower mortality than having a trained birth attendant (2003). Their finding of the importance of access to family planning in the reduction of maternal mortality echoes a similar finding by Sloan et al. (2001). Contraceptives can also reduce abortion in countries where use is able to keep pace with the demand for fertility regulation (Marston and Cleland, 2003). In Malawi, only 4% of women interviewed after presenting at health care providers with incomplete abortions were using a contraceptive method at the time of their latest pregnancy (Kinoti et al., 1995).

Introduction

Analysis of spatially referenced health data can identify a gradient of access to specific services and determine whether and how the gradient affects the utilization of services. In the case of family planning, it is possible to determine whether individuals within communities with more limited access to existing service delivery infrastructure are less likely to use contraception. If low access to contraceptive services is not associated with low use, then it could be that existing services adequately meet current demand. Desired fertility varies within countries and people with less access may also have less desire to use contraception. However, the presence of unsafe abortion runs counter to this hypothesis and the lack of relationship may instead be due to poor measurement of access. Previous work has often used Euclidean distance[1] or travel time as a measure of access, but a more sophisticated measure of access may be necessary.

Previously researchers generated accessibility indicators based on Euclidean distance to services, travel time, and poverty measures using geographic information systems (GIS), (Rosero-Bixby, 2004; Tanser et al., 2001; Bigman and Deichmann, 2000; Entwisle et al., 1997; McDevitt et al., 1996). A better understanding of spatial variability in contraceptive utilization could allow health planners to make better use of scarce resources to improve access to family planning services and specific methods of contraception. In countries under extreme resource constraints, spatial analysis may allow health planners to enhance the coverage of services by targeting their interventions to those who lack access (Tanser and le Sueur, 2002; Deichman, 1999).

Knowledge of whether and how the continuum of access affects use of contraception would be a useful input in the design of interventions. The ability to quantify access would allow health planners to identify trade-offs between increasing access by a certain quantity versus allocating funds to another intervention intended to increase contraceptive use. This paper employs spatial analysis to explore access to family planning with the hypothesis that the utilization of family planning services is, in part, a function of geography.

[1] The straight line distance between two points or distance "as the crow flies."

Literature review

Easterlin improved upon previous economic theories of contraceptive adoption by broadly defining cost as a barrier to contraceptive to include psychic barriers, lack of access to ideas or services, and social and economic costs (1975).

Appendix I provides a broad overview of the peer-reviewed literature as it relates to research investigating travel-time or physical proximity as determinants of contraceptive use. The literature review was governed by inclusion criteria that papers use travel-time or physical proximity as a proxy for access to family planning. Papers needed to be written in English and references to travel time or physical proximity and access to family planning needed to appear in the article's abstract. No limit was placed on the date at which the paper was published.

PubMed, and Google Scholar searches of the terms "access distance family planning," "access travel time family planning," "access density family planning," "access distance contraception," "access travel time contraception," and "access density contraception" produced 44 papers that met the criteria for inclusion. All hits from the PubMed search were viewed. All hits from the first 50 pages of the Google Scholar search were viewed. The studies range in date from 1967 to 2004, indicating the continued interest in the effect of geography on contraceptive use. The appendix matrix shows that 28 of the 44 papers offer some support for the hypothesis that utilization of family planning services is a function of geography. Nevertheless, it would be inappropriate to suppose that the 28 papers represent a confluence of evidence.

The methodological sophistication of the work varied considerably. Some authors made claims based on simple cross tabulations of data. These studies did not control for other causal factors, which causes doubt regarding the conclusions of the authors. Other studies controlled for an array of potential confounders and potential sources of error. Both classes of study hold examples of positive and negative findings for the effect of travel-time or proximity as determinants of contraceptive use. The matrix provides a useful summary of the relevant literature, but greater understanding required an in depth analysis of the content of the literature. What follows is an engagement of some of the more rigorous works that presented negative and positive findings with regard to physical barriers as determinants of contraceptive use.

Positive findings

Evidence suggests that geography affects use of modern contraception, at least at certain phases of the fertility transition. Research specific to Malawi suggests that, in the past, low utilization rates were associated with lack of access to modern methods (Kalipeni and Zulu, 1993). Others have found more general evidence that access, as measured by reported proximity to a supply source, is positively and significantly correlated to modern contraceptive use (McDevitt et. al., 1996; Steele et al., 1999; Entwisle et al., 1984; Fuller, 1974; Fawcett et al., 1967).

In a seminal study, Fawcett et al. demonstrated the association between distance to a Bangkok IUD clinic and the number of users (1967). Although highly motivated women were willing to travel 200 kilometers to obtain IUDs, the number of adopters dropped steeply with increasing distance.

Steele et al. found that postpartum adoption of a modern contraception method differed significantly in Morocco from 43 percent among those women who had no nearby health center to 64 percent among women for whom there was a health center within 10 kilometers (1999).

Entwisle et al. recorded a strong availability effect in their study of rural Thailand (1984). In a multilevel model, a macrolevel measure of accessibility was defined for villages as being less than 4 kilometers from district or subdistrict health centers. Specifically, living in a village near a subdistrict health center increased the odds of contracepting by 80 percent among women with less than a primary education.

A substantial body of work shows that perceived and objectively measured travel time is inversely related to contraceptive use (Hammerslough, 1992; Tuladhar, 1987; Chen et al., 1983; Cornelius and Novak, 1983; Tsui, 1982).

Hammerslough's study of the Kenyan fertility decline in the 1980s indicates that contraceptive availability did not initiate the transition but probably hastened the decline. His results show that women who lived further than three hours travel time from a source of contraception were 44% less likely to have ever used contraception and 42% less likely to be a current user of contraception (1992).

In a study of contraceptive availability and use in Costa Rica, Thailand, Colombia, Honduras, and Nepal, Cornelius and Novak observed significant reductions in contraceptive prevalence with increases in time to supply source (1983). Similarly, a study of Nepalese women provides evidence that travel time can act as a barrier to contraceptive use by establishing that the proportion of current users of contraception decreased as travel time to reach an outlet of family planning increased (Tuladhar, 1987). After controlling for ethnicity and socioeconomic factors, Chen found a pronounced depressing effect of time to services on use of reversible contraceptive methods among Ladinos in Guatemala (1983).

Controlling for years since first marriage, number of living children, urban-rural residence, education, and desire for more children, Rodriguez found that in four developing countries, use of modern contraception increased as perceived travel time to a family planning outlet decreased (1979). The question of whether perceived time to services affects use was also taken up by Tsui (1982). She concluded that both perceived and actual accessibility to family planning can increase contraceptive prevalence and reduce unmet need.

Negative findings

Some research has found that time, distance, and subjective perceptions of accessibility do not play an important role in contraceptive use (Mroz et al., 1999). Similar findings exist regarding unmet need for contraception (Westoff and Bankole, 1996; Bongaarts and Bruce, 1995). Each of these studies however contained weakness that could have caused the researchers to miss a spatial effect.

Mroz et al. found that most rural Tanzanian communities in their study had a family planning dispensary within 30 kilometers (1999). However, only 3.2% of the sample population used a modern method. It could be that proximity to family planning is a major factor in determining use but not until the fertility transition is under way.

TFR had declined for the Tanzania as a whole from 6.9 in 1978 to 6.3 in 1991/1992, the date of Mroz's data (Cohen, 1998). A 9.5% change, such as this, signals the onset of a country's fertility decline, which is said to commence the year that total fertility drops to 5 per cent below the maximum observed level (Bongaarts, 2002). However, in the interval between the 1991/1992 and 1996 DHS surveys, rural fertility dropped less than 5% while urban fertility dropped 25%. With the fertility transition barely or not at all underway in rural areas of Tanzania, it is difficult to say that access is not a factor in nonuse.

Westoff and Bankole's analysis of DHS surveys from 27 countries notes that access is the least cited reason for nonuse (1996). In another examination of DHS surveys, Bongaarts and Bruce do not dismiss geography as a barrier to use. However, they claim that travel costs, along with monetary costs, are a modest contributory factor to unmet need for family planning when compared to the social environment in which decisions about family planning are made (Bongaarts and Bruce, 1995).

Bongaarts and Bruce cite a weakness of the DHS's method that bears on their finding that access is not a major contributing factor to unmet need. DHS surveys limit respondents to only one major reason for not using contraception. However, it is likely that respondents have multiple reasons for not using contraception. The DHS would fail to record whether inconvenience, distance, or travel time were consistently the second or third main reason for nonuse. What's more, primary reasons given for opposition to family planning may in part be caused by a lack of exposure to family planning service delivery points.

More importantly, individuals are intimately familiar with household barriers such as family member resistance. In order to identify access as a barrier, one must actually attempt to gain access or learn from others who have made such an effort. The potential for access to be a barrier cannot be explored by identifying only the primary reason for not using family planning. This weakness in the DHS also applies to the conclusions of Westoff and Bankole.

Measurement error may also weaken much research into the effect of proximity on contraceptive use (Bertrand et al., 1995). As with any survey, DHS studies may fail to account for the difficulty individuals may have when reporting on phenomena they haven't fully considered or attempted. In other words, self-report may underestimate what barriers individuals face when they attempt to gain access. Time series analysis indicates that increases in supply side access to contraceptives can affect use, notably among those who previously expressed no interest in use (Magnani et al., 1999).

It is possible that what Magnani et al. observed was in part due to a positive effect of contraceptive availability on knowledge and attitude as well as access. According to Easterlin, programs lower subjective costs by "lending legitimacy to the notion of practicing birth control." Higher facility density could also affect knowledge of contraceptive methods, such as where to access, the price of access, how to use methods, and what their side effects are likely to be. Increases in knowledge might then increase the desire to contracept. Facility presence could have a similar effect on community attitudes and beliefs. Conversely, if access is poor, the notion of practicing birth control may lack legitimacy to the individual as well as the society.

Previous work (Heard, Larsen, and Hozumi, 2004) failed to find a statically significant relationship between Euclidean distance to family planning services and use of modern contraception in Malawi. However, it is possible that the category of "modern contraception" might have been too broad. In other words, the differing spatial distribution of the availability of specific methods of contraception may have masked a distance effect. For example, facilities that offer vasectomy and tubal ligation would only be available at a subset of facilities that offer modern contraceptives and are surely less common than facilities that offer condoms.

Therefore, distance could affect use of some methods and not others. Levin et al. indicates the plausibility of this interpretation by showing that women who needed to travel further distances to family planning outlets were less likely to use IUDs, which require follow up visits (1999). Heard, Larsen, and Hozumi, 2004 was among the first published efforts to use DHS data in this way (2004; see Seiber and Bertrand, 2002 for another example). The methodology and analysis of the current study builds on this previous effort by using a more sophisticated measure of access and a multilevel model to allow for correlation within clusters.

Data

This study draws upon the 2000 Malawi Demographic and Health Survey (MDHS) and 2003 Malawi Health Facilities Inventory (MHFI). The United States Agency for International Development (USAID) conducted a DHS survey in Malawi in 2000, with 13,220 women being interviewed in 560 clusters over a period from July to November (MDHS, 2001, pp. 4-7).

The scope of the DHS surveys covers a wide range of questions regarding contraceptive practice, knowledge, and perception. These surveys provided all of the data involving human subjects required to analyze the spatial variability of contraceptive practices in Malawi. Since 1997, DHS surveys have included geocode that allows users to analyze data spatially at the cluster level (Macro International Inc., 2000 p.2). This underutilized feature of the DHS opens the possibility of a completely new kind of analysis of contraceptive behavior.

This study's sample was composed of sexually active, non-pregnant women who have not entered menopause or had a hysterectomy. In short, the analysis was limited to women who were "at risk" of using contraception. There were 10,101 of these women in MDHS. Table 1 displays the number of nonusers and users of the four most common methods.

Table 1. The four most common methods of modern contraception in Malawi, 2000 MDHS N = 10,101

	Frequency	Percent of total (10,101)
Nonusers	6830	67.6
Injections	1596	15.8
Female sterilization	513	5.08
Pill	306	3.03
Condoms	277	2.74

The MHFI provides the other dataset to be used in this study. All public, nongovernmental, and mission operated facilities above health center level, voluntary HIV counseling and testing

centers, some private facilities, MOHP offices, and rehabilitation centers in Malawi were included in this inventory. Data collectors gathered information on the structural characteristics of buildings, human resources, the available healthcare services, ownership, and GPS coordinates. Detailed questionnaires were administered at 672 facilities (Miller, 2003).

MHFI does not contain comprehensive data on private facilities. If the primary market for contraceptives is the private sector, statistical analysis could underestimate a density effect on use. However, the government and NGO sectors are the source of contraception for at least 80% of women who use injection, female sterilization, and the pill (MDHS, 2001).

In addition, the most common private provider of contraceptive methods is Banja La Mtsogola, for which data does exist in the MHFI. Table 2 depicts the market for contraceptives in Malawi. Unfortunately, available data does not include information on shops, the source of condoms for 48.4% of Malawian women. This blind spot in the data precludes the study of the relationship of density of outlets on condom use.

Table 2. Sources of the four most common methods of modern contraception in Malawi, 2000 MDHS

	Injections	Female sterilization	Pill	Condoms
Government Clinical/Pharmacy	74.01	39.96	54.58	31.64
Government Home/Community delivery	5.52	0.00	12.09	6.55
NGO	5.27	39.96	13.40	7.64
Private Clinic	15.19	19.88	18.95	5.09
Private Pharmacy	0.00	0.00	0.00	0.36
Shop, church, friend	0.00	0.00	0.98	48.36
Other	0.00	0.19	0.00	0.19

Method

This paper makes use of preexisting datasets and new variables that can be generated by combining extant datasets in a GIS using ArcGIS 9 (ESRI) software. A GIS can layer different spatially referenced datasets and measure spatial relationships based on the locations of database features. ArcGIS 9 contains a suite of spatial analytic tools, including those that measure the distance between geographic features, calculate the density of units per specified area, and nominate suitable locations for new health facilities based on user-defined criteria.

Figure 1 illustrates how GIS layers separate datasets to create an environment where the user can calculate distance between household clusters and the nearest major road or nearest health facility that offers family planning services. A GIS is not simply a means of merging datasets on a feature that the datasets share. The GIS can generate new information that neither dataset contained previously.

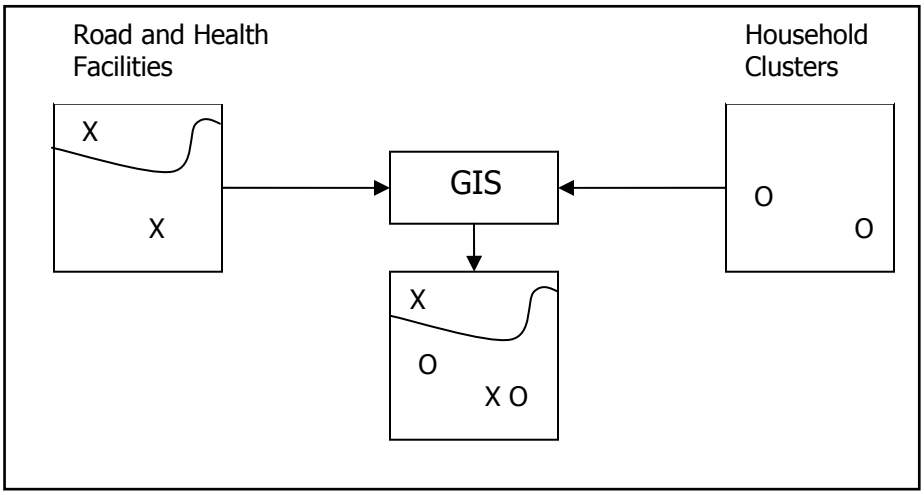


Figure 1. Data on geographic features can be merged with household cluster data to allow measurement of distance from households to roads or health facilities

GIS provides an accurate and inexpensive tool for generating objective spatial measures, thereby allowing researchers to investigate logistic efficiency and questions of access to services in a way that was not practicable before.

Previous research demonstrated that DHS data could be integrated with MHFI data to produce the exact distance between DHS sample clusters and health facilities that offered family planning services (Heard, Larsen, and Hozumi, 2004). Figure 2a shows all of the health facilities that offer family planning in Dedza, Malawi. Figure 2b depicts the health facilities as circles and DHS sample clusters as crosses.

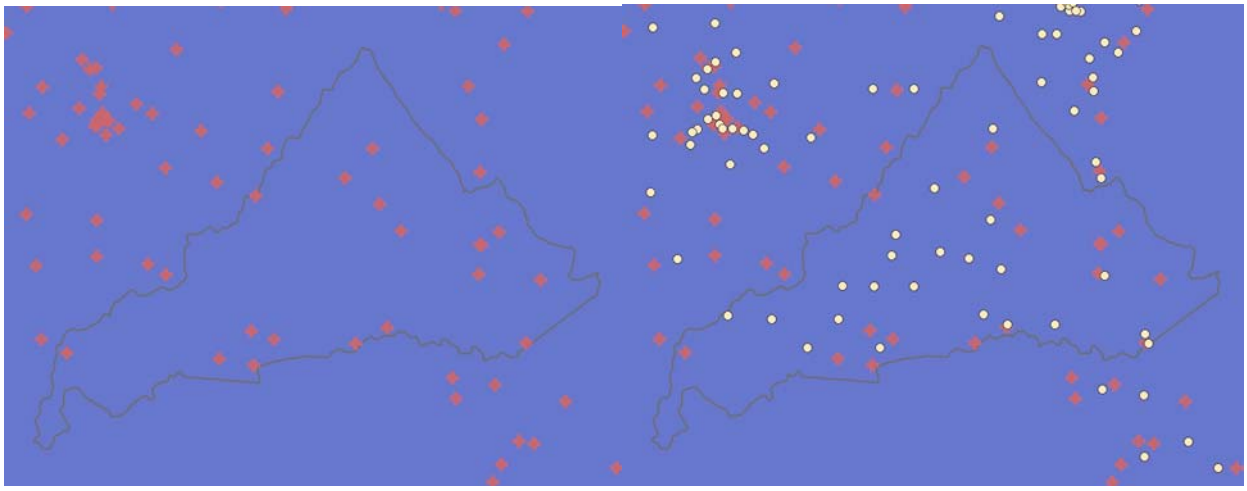


Figure 2a. Family planning services delivery points in Dedza, Malawi

Figure 2b. Delivery points merged with DHS sample clusters

This paper is based on a hypothesis that grew from consideration of the results of this previous work (Heard, Larsen, and Hozumi, 2004). I now hypothesize that density of contraceptive service availability is a better proxy for access to contraceptives than Euclidean distance in the

sense that density captures several important effects that Euclidean distance does not. Euclidean distance only accounts for the nearest facility and does not model the possible effect of facilities that are slightly further but more convenient for other reasons.

Higher density of services increases the convenience of accessing the services by enhancing the probability a person will encounter a facility over the course of a normal day's travels. High service density may also have an effect on a person's perception of contraception, making it seem commonplace and acceptable. Euclidean distance captures neither of these possible effects.

ArcGIS 9 provides the ability to account for neighborhood effects of service availability presence by modeling density using a technique called kernel density estimation, described later. Figure 3a illustrates an application of kernel density estimation. Point data on facilities that offer family planning converts to a continuous surface with blue areas representing low density and red areas representing high density. Figure 3b locates DHS clusters on the continuous surface, demonstrating how density can be linked to information on the contraceptive practices of survey respondents. It is the unique capacity of GIS that allows the analysis of such spatial features and their relationships.

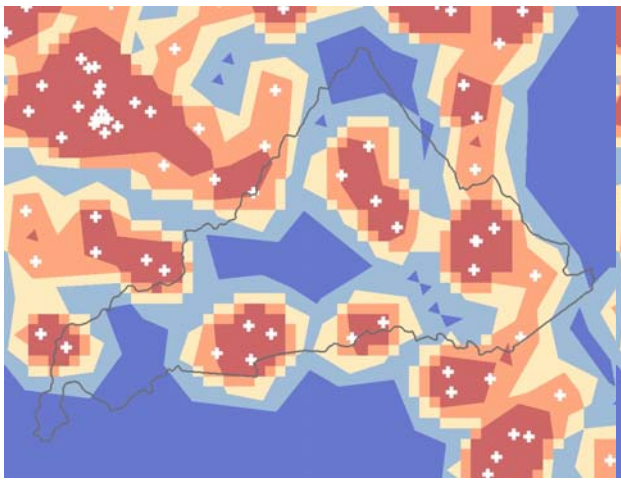


Figure 3a. Family planning facilities as white crosses and as a density surface (low=blue, high=red) in the district of Dedza, Malawi

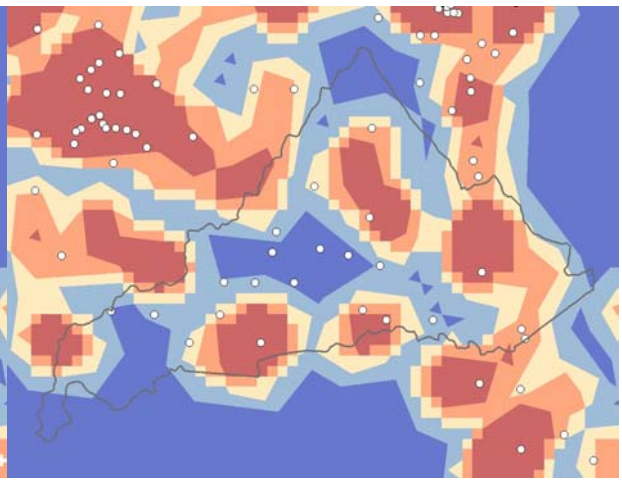


Figure 3b. The same density surface with DHS sample cluster locations

This analysis assessed determinants of use of specific contraceptive methods. Rather than studying use of modern contraceptives the three most common methods were assessed individually: injection, female sterilization, and the pill. The main independent variable of interest in this study was the density of outlets that offered modern methods of contraception. The density variable was created by converting all of the latitude and longitude coordinates for each facility that offers a service into a continuous surface. The principle of the process can be grasped intuitively by viewing figures 3a and 3b above.

Tsui et al. conducted an analysis of family planning density on contraceptive use in Korea, Mexico and Bangladesh and found that respectively, high family planning density was associated with a 71, 83, and 54 percent higher probability of contraceptive use when compared to residents of low density (1981). This strong finding persisted after controlling for parity, community development, marital duration and education. Tsui et al. used a simple notion of density, defining access as the number of sources within 5 kilometers. The difference between simple density and kernel density estimation lies in the ability of the kernel to weight the presence of health facilities that are at the center of the radius higher than health facilities at the periphery. As a result, kernel density models a more realistic sense of the effect of space on human action.

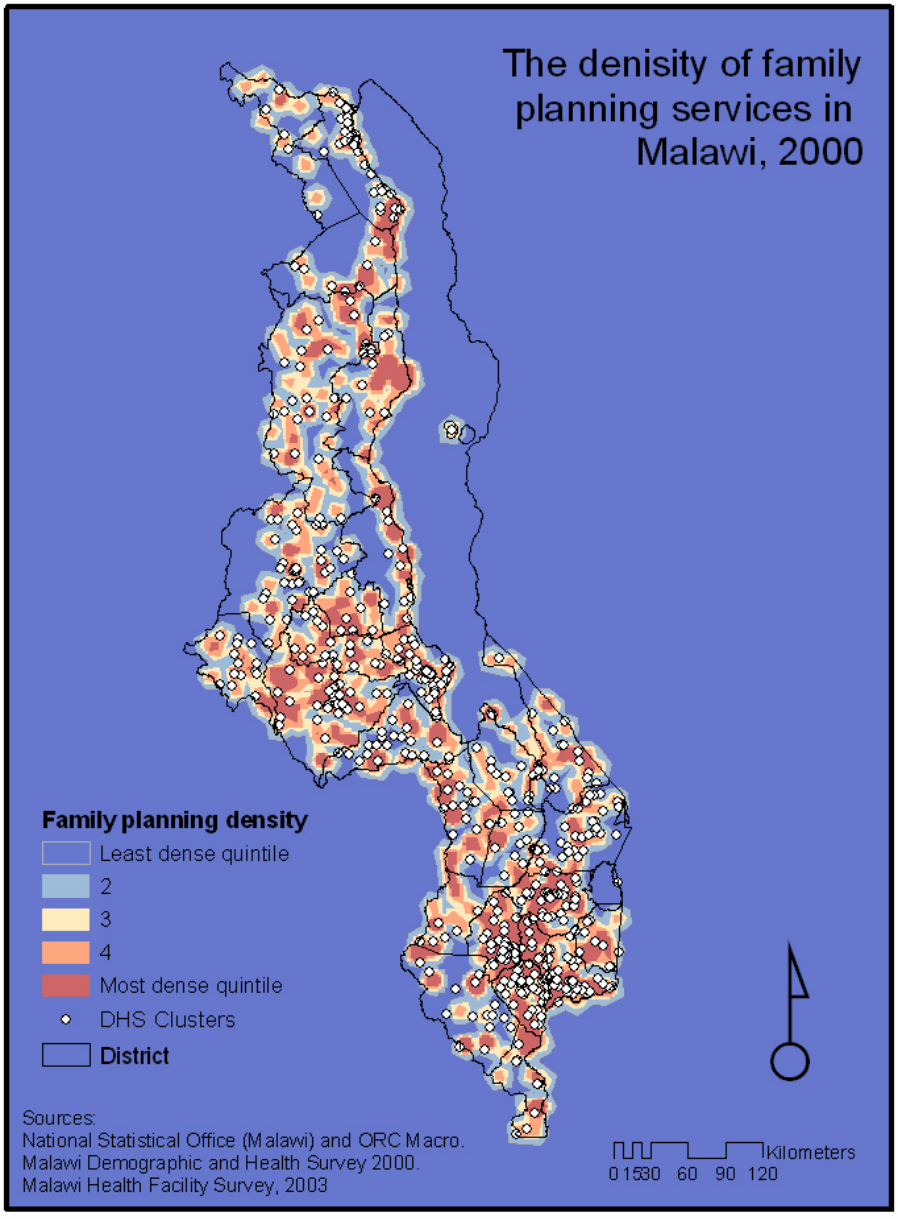


Figure 4. The density of family planning services in Malawi.

Kernel density estimation allows specification of the kernel as well as the size of the grid cell into which the density measure is contained. The surface was created in ArcGIS with MHFI family planning service point data. After McLafferty and Guagliardo et al, the choice of grid cell size was based on an estimate of the distance at which accessibility declines (2004, 2004).

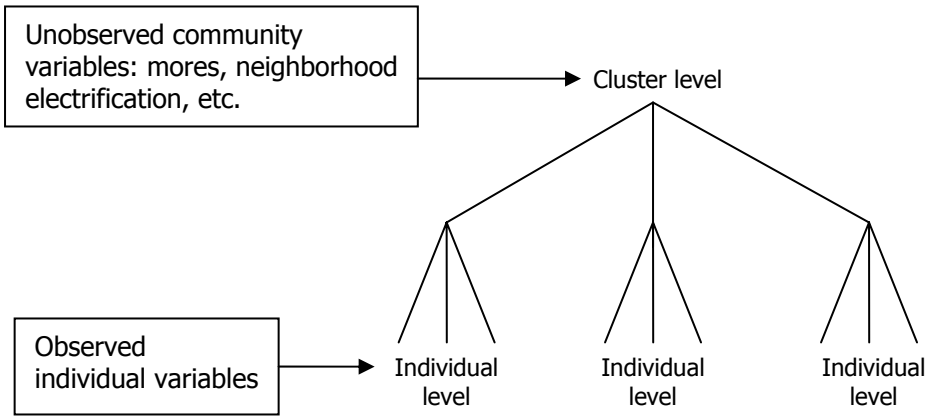
This study uses a 20 kilometer search radius which represents 5 hours of travel time by foot, the presumed upper limit of accessibility given a 4 kilometer per hour walking speed. Access to a means of transportation would change the effective range of individuals, however fewer than half of survey respondents had a bicycle (MDHS, 2001) and only 1.4 percent and 2.4 percent had motorcycles or cars, respectively.

Beneath the kernels is a grid composed of two-square kilometer cells that divide the grid into sections that could be traversed in approximately 30 minutes. Kernel density estimation gives each 2 km cell a value that is the weighted sum of facilities in the cell itself and the cells within the 20 km radius, giving highest weight to the cell itself and lowest weight to the cells at the periphery of the radius.

Model

Many unobserved macro-level factors could affect micro-level individual contraceptive behavior (Figure 5). Among these macro-level influences could be community mores or neighborhood electrification (Entwisle, 1985; Diez-Rou, 2000). The multilevel model can allow random effects at the community (cluster) level to capture the effect of these omitted variables.

Figure 5. A multilevel model



The multilevel model design also allows researchers to account for possible correlation within sample clusters. The failure to correct for clustering violates the independence assumption and can lead to distorted parameter estimates and standard errors (Guo, 2000). SAS provides a flexible program that is well suited for fitting multilevel models that include fixed and random effects. The NLMIXED procedure allows for the modeling of cluster-level random effects. The model employed in this paper is based on Heard, Larsen, and Hozumi (2004).

The variables in that model were modified slightly by replacing the flooring variable with a wealth index, which has recently been made available by ORC Macro. The essential difference between this analysis and the previous one is the inclusion of the density parameter and a random effect estimator, u, to allow for within-cluster correlation. The model for use of injection contraception is specified as follows:

$$\text{Logit}[\textit{use of injection contraception}_{ij}] = \beta 0 + X'_{ij}\beta + u_j + e_{ij}$$

where use of injection contraception is a binary dependent variable and X is a vector containing the following variables: medium family planning density, low family planning density, never married, formerly married, rural, partner's education none, partner's education secondary or higher, partner's education missing, age, primary education, secondary and above, parity, non Catholic Christian, Muslim, No religion, media high, frequency high, and wealth index, for each

person *i* in community (cluster) *j*. "u" is the random effect at the community level and e is the error term at the individual level.

Results

Summary statistics for the sample population are displayed in Table 3. It presents the distribution of users and nonusers of contraception by density. As a general trend, the percentage of women using modern contraceptives decreased with density. The percentage of non-users of any kind of contraception, including traditional forms that are not modern, increased as family planning density decreased.

Table 3. Distribution of contraceptive users and nonusers (N = 10,101)

	N	Modern method (2767)	Non-users (6830)	Injection (1596)	Sterilization (513)	Pill (306)
Family Planning Density						
High	4946	31.16%	64.51%	17.74%	6.31%	3.28%
Medium	3155	24.03%	70.14%	14.23%	3.80%	2.73%
Low	2000	23.40%	71.35%	13.50%	4.05%	2.90%

Table 4 displays results from the multilevel model. The complete tables can be found in the appendices to this paper. In general, density was a powerful predictor of contraceptive use, with lower density exerting a negative effect on use. Women who lived in low density family planning service availability were 20% less likely to use any form of modern contraception.

Disaggregating by method, it was shown that density was not a predictor of use of the pill. However, use of injection contraception and sterilization was affected. For a given cluster, women who lived in areas with medium or low density family planning were significantly less likely to use injection contraception than women who lived in areas with high density family planning. Exponentiation of beta coefficients shows that women who lived in medium and low density areas were 25% and 30% less likely to use injection contraception compared to women in high density areas. In short, access to contraceptive services increased use of injection contraception.

The effect of density on use of sterilization was even stronger than for injection contraception. Compared to women who live in areas with high density family planning women in medium and low density areas were less than 30% as likely to have been sterilized. In short, when family planning services are denser, women are more likely to use sterilization.

The variance of the error term was relatively large and significant, indicating that it is important to account for the clustered nature of the data. Therefore, this form of the model is superior to a simpler logistic regression that doesn't allow for correlation within sample clusters.

Table 4. Adjusted[1] effect estimates of density on use of various methods of contraception

Parameter	Estimate	Standard Error	Pr > |t|	Lower	Upper
Modern Contraception					
Family planning density $_{medium}$	-0.192	0.077	0.0132	-0.344	-0.040
Family planning density $_{low}$	-0.224	0.088	0.0108	-0.397	-0.052
s2u	0.167	0.031	<.0001	0.106	0.229
Injection Contraception					
Family planning density $_{medium}$	-0.284	0.097	0.0035	-0.474	-0.094
Family planning density $_{low}$	-0.363	0.111	0.0011	-0.580	-0.146
s2u	0.268	0.051	<.0001	0.168	0.367
Female Sterilization					
Family planning density $_{medium}$	-0.461	0.164	0.0051	-0.783	-0.139
Family planning density $_{low}$	-0.382	0.184	0.0388	-0.744	-0.020
s2u	0.501	0.127	<.0001	0.251	0.751
The Pill					
Family planning density $_{medium}$	0.133	0.179	0.4579	-0.218	0.483
Family planning density $_{low}$	0.171	0.196	0.3838	-0.215	0.557
s2u	0.276	0.142	0.0517	-0.002	0.554

[1]Adjusted for never married, formerly married, rural, partner's education none, partner's education secondary or higher, partner's education missing, age, primary education, secondary and above, parity, non Catholic Christian, Muslim, No religion, media high, frequency high, and wealth index. Full tables are in appendices.

Discussion

It is possible that the relatively high percentage of government home and community delivery of the pill masked a density effect. Approximately 12% of women gain access to the pill through this service for which there was no spatial data. That lack of data could obscure a density effect.

Another insight to come from this analysis is that with density in the model, there was no distinction between urban and rural residence in term of modern contraceptive use. This

indicates that the commonly observed urban-rural divide in contraceptive use might be attributable to differences in contraceptive density.

MHFC did not contain information on the availability of specific methods of contraception. Some facilities that contributed data to the construction of the density surface would not have offered every method under investigation. As a result, models of the use of specific methods of contraception may underestimate the effect of a density surface representing the availability of those methods.

[To be expanded]

Facility siting decisions are sometimes based on political considerations with little formal analysis (Rahman and Smith, 1999). Recent research has brought techniques for determining optimal locations for health services to developing countries (Kumar, 2004; Khan et al., 2001; Møller-Jensen and Kofie, 2001; Rahman and Smith, 2000). The primary concern has been to make health care more accessible by minimizing distance or travel time to facilities.

The 2001 Human Development Report is entitled *Making new technologies work for human development*. The report opines that the public policy can ensure that the benefits of new technology do not widen current inequalities between the rich and poor (UNDP, 2001).

Conclusion

This paper demonstrated that family planning service density is a strong determinant of contraceptive use.

Results captured heterogeneity of access within the study country and provided an example of how GIS can be used to model accessibility to health services in developing countries.

The paper elucidated the impact accessibility has on contraceptive use and suggested how this information could be used to better place new facilities or additional contraceptive services.

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Appendix I. Literature review of research investigating travel-time or physical proximity as determinants of contraceptive use

Author	Area of study	Data	Dependent variable	Travel-time or physical proximity variable	Method	Finding
Agha, 1998	Zambia	1996 Lusaka Sexual Behavior and Condom Use Survey	Use of condom at last intercourse	Travel time to source of condoms	Logistic regression	Men were nearly twice as likely to have used a condom when less than ten minutes from a source compared to those more than ten minutes from a source
Ali, 2001	Egypt	Egypt DHS-I, 1988	Conitnuation of pill use	Proximity score based on mean straveling tme from the center of the village to family planing facilities	Random effects	The proximity score was not a significant predictor.
Angeles et al., 1998	Tanzania	1991/2 Tanzania Demographic and Health Survey	The effect of access to family planning on births by age 34	Presence of various types of health facility within 5 kilometers	Semiparametric random-effects maximum likelikood model	Nearby hospitals depress births by 18.6%, neaby health centers depress births by 21% and dispensaries depress births by 10.9%.
Awoonor-Williams et al., 2004	Ghana	2002 Nkwanta district-level survey	Relative risk ratios for knowing about and practicing contraception compared with not knowing about contraception	Distance to service point	Logistic regression	Distance has a small but significant depressive effect on use.
Becker et al., 1993	Philippines	Barangays survey, July 1988 and January 1989	Use of modern contraception	Minutes to facility	Trichotomous logistic regression	In rural, areas increased travel time to family-planning source was associated with lower use of contraception.
Bertrand et al., 2001	Guatemala	DHS surveys from 1987 and 1995-1996, and a mini-DHS from 1998	Use of modern contraception	Minutes to facility	Logistic regression	Mayan women who live within ten minutes of services were 2.3 times as likely to use contraception as those who lived a further distance.

Author	Area of study	Data	Dependent variable	Travel-time or physical proximity variable	Method	Finding
Bongaarts and Bruce, 1995	Multiple	DHS data from 13 countries	Unmet need for contraception	Self-report that contraception is difficult to get	Cross tabulation	Access is relatively unimportnat. Increasing density should not have a strong effect on unmet need where density is already high.
Casterline et al., 2001	Pakistan	Punjab province, 1996	Intention to use contraception in the future	Perceived proximity of nearest services in minutes on foot	Measured indicators regressed on the latent variables; latent variables regressed on the background variables; and intention to use regressed on the latent variables	Access to contraception is not a strong a barrier to intention to use contraception in the future among nonusers who express a desire to avoid pregnancy
Casterline et al. 1997	Philippines	Structured and semistructured interviews	Unmet need for contraception	One or more methods: "do not know where to obtain"; one or more methods: "difficult to obtain"	Multiple logit regressions	Access is unimportant as a determinant of unmet need
Chen et al., 1983	Guatemala	The 1978 National Survey of Fertility, Family Planning and Communication of Guatemala	Percentage of married women using a reversible method of contraception	Travel time to the nearest contraceptive source	Factor analysis with principal component method, with orthogonal quartimax rotation	There is a depressing effect of time to services on use of reversible contraceptive methods among Ladinos in Guatemala
Churchill et al., 2000	England	Data from the Trent Focus Collaborative Research Network	Contraceptive acceptors who later became pregnant	Miles from facility	Conditional logistic regression	Adopters were more likely to live within two miles of the facility.
Cornelius and Novak, 1983	Costa Rica, Thailand, Colombia, Honduras, and Nepal	Contraceptive Prevalence Surveys, 1980 and 1981	Contraceptive prevalence	Time to source of contraception in minutes	Multiple classification analysis	Significant reductions in contraceptive prevalence accompany increases in time to supply source.

Author	Area of study	Data	Dependent variable	Travel-time or physical proximity variable	Method	Finding
Diamond et al., 1999	England	National Health Service database and the British Pregnancy Advisory Service, 1991 and 1994	Teen pregnancy	Self-report of being near	Multilevel model	Young people were 1.10 times more likely to become pregnant when living between 7 and 10 kilometers from the nearest youth-oriented clinic compared to youth who lived less than 7 kilometers from such clinics.
Entwisle et al., 1984	Thailand	Thailand Contraceptive Prevalence Survey	Use of modern contraception	Villages as being less than 4 kilometers from district or subdistrict health centers	Multilevel model	Living in a village near a subdistrict health center increased the odds of contracepting by 80 percent among women who want no more children and with less than a primary education.
Fawcett et al., 1967	Thailand	Chulalongkorn Hospital records	Number of IUD acceptors from a given province in 1965	Distance of province to Bangkok	Cross plot	Greater distance is associated with fewer adopters.
Fuller, 1974	Chile	University of Chile annual survey of San Gregorio, 1967	Use of modern contraception	Euclidean distance from household to the nearest clinic that offers family planning	Principle component analysis	Distance is a powerful discriminator between users and nonusers of contraception
Godley, 2001	Thailand	1994 household survey in 51 villages in Nang Rong, Thaliand	Temporary contraceptive method choice	Distance to health centers	Multinomial logitic regression	Increased distance has a slight but significant negative effect on use of the pill and the IUD.
Guilkey and Jayne, 1997	Zimbabwe	1989 Zimbabwe Demographic and Health Survey	Use of modern method vs. use of no method	Whether various types of facilities within 5 km of community offer family planning	Maximum likelihood estimation	Access to all types of health facilities with family planning was not significantly associated with use of modern contraception.

Author	Area of study	Data	Dependent variable	Travel-time or physical proximity variable	Method	Finding
Hammerslough, 1992	Kenya	1989 Kenya Community Survey and Kenya Demographic and Health Survey	Proportion of women currently using a clinical method	Travel time to nearest source of family planning	Logistic regression	Increase in availability of contraceptive services accelerated the fertility transition. Women who lived more than three hours away from a source of contraception were much less likely to use a clinical method.
Heard, Larsen, and Hozumi, 2004	Malawi	2000 Malawi DHS	Use of modern contraception	Distance to the nearest health facility that offers family planning and youth-friendly services or HIV testing or HIV counseling or 24-hour services	Logistic regression	Distance was insignificant.
Hubacher et al., 1996	Honduras	1987 and 1991-1992 Epidemiology and Family Health Survey	Chosing withdrawl over a modern method	Travel time to health facility	Logistic regression	Compared to women who live less than one hour from a health facility, women who live 1-2 hours away are 46% more likely and women who live greater than three hours away are 92% more likely to use withdrawl.
Janowitz et al., 1983	Honduras	Survey data from two Ministry of Health hospitals	Sterilization	Travel time to sterilization facilities	Cross tabulation	Travel time was not associated with the percent of women sterilized.
Jones and Kirigia, 2000	South Africa	South African National Household Survey of Health Inequalities in 1994	Contraceptive use	Travel time to and from source of contraception	Multinomial logistic regression	Greater travel time reduced use of the pill.
Kamal et al., 1999	Bangladesh	Sub-samples of the 1991 Contraceptive Prevalence Survey	Use of reversible modern contraception	Distance from family planning retail shop	Random effects	Distance was insignificant.

Author	Area of study	Data	Dependent variable	Travel-time or physical proximity variable	Method	Finding
Katende et al., 2003	Uganda	1999 Delivery of Improved Services for Health Evaluation Surveys	Use of modern contraception	Number of public and private facilities offering family planning in the community	Multivariate logistic regression models	Rural areas: Two facilities offering pills, condoms and injectables in the community were 1.7 times as likely to be currently using a modern method. Urban areas: One or more private facilities offering family planning services in the community were 2 times as likely to be currently using a modern method.
Levin et al., 1999	Bangladesh	A survey on use of contraception and two baseline surveys of 1993 and 1994 in the two field sites of the MCH-FP Extension Project (Rural) of International Center for Diarrhoeal Disease Research, Bangladesh.	Contraceptive use	Travel time to nearest clinic	Logistic regression	Women who needed to travel further distances to family planning outlets were less likely to use IUDs, which require follow up visits.
Magnani et al., 1999	Morocco	1992 Morocco DHS-II Survey and the 1995 Morocco Panel Survey	Future contraceptive use	Method availability at the nearest public clinic	Two-equation bivariate probit model	Women who lived near public clinics with family planning were substantially more likely to use contraception.
Mroz et al., 1999	Rural Tanzania	1991/2 Tanzania Demographic and Health Survey	Use of modern contraception	Family planning facility within 30km at age 12	Two-stage least squares and maximum likelihood model	No effect
Muhwava, 2003	Zimbabwe	1988 and 1994 Zimbabwe Demographic and Health Surveys	Current contraceptive use among currently married women.	Motorized access to family planning hospital and walking access to family planning hospital; motorized access to family planning clinic and walking access to family planning clinic	Three-level Logistic Regression Model	Not statistically significant

Author	Area of study	Data	Dependent variable	Travel-time or physical proximity variable	Method	Finding
Nazar-Beutelspacher et al., 1999	Mexico	Encuesta Regional de Salud Reproductiva, 1994	Non-use of contraception	Distance to the nearest clinic	Bivariate analysis	Distance was insignificant.
Paul, 1991	Bangladesh	Sample survey, 1984	Use of modern contraception	Distance to facility offering clinical methods of family planning	Logistic regression	No observable distance decay effect
Pebley and Brackett, 1982	Multiple	Seven World Fertility Surveys	Use of modern contraception	Travel time to an outlet of family planning	Logistic regression	Use decreases with increased travel time family planning outlet. However, once an outlet is known, travel time makes little difference.
Robey et al., 1996	Multiple	Literature review	Unmet need for contraception	Distance to a source of contraception	Literature review	Distance bears little relationship to unmet need
Rodriguez, 1979	Multiple	11 World Fertility Surveys	Use of modern contraception	Perceived travel time to the nearest contraceptive source	Hierarchical analysis of covariance	As travel time decreases, use increases
Ross, 2002	Multiple	World Fertility Surveys, Contraceptive Prevalence Surveys, and Demographic and Health Surveys from 64 countries	Contraceptive prevalence	Spending no more than an average of two hours per month to obtain services or supply. Cost of one month's supply should be less than 1% of a month's wages.	Cross plot	"In general, the prevalence of use of each method follows its availability, the mean prevalence of all methods follows mean availability and total prevalence follows the availability of several methods that are each easily available."
Seiber and Bertrand, 2002	Guatemala	1995/6 Guatemala DHS and 1997 Providers Census	Use of modern contraception	Distance to the nearest health facility that offers family planning	Cross tabulation	Physical access does not appear to be a decisive factor of use or nonuse
Steele et al., 1999	Morocco	1992 Morocco DHS-II Survey and the 1995 Morocco DHS Calendar	Postpartum adoption of a modern contraception method	Health center within 10 kilometers	Multilevel event history model	Dependent variable differed significantly from 43 percent among those women who had no nearby health center to 64 percent among women for whom there was a health center within 10 kilometers.

Author	Area of study	Data	Dependent variable	Travel-time or physical proximity variable	Method	Finding
Sultan et al., 2002	Pakistan	1996/7 Pakistan Fertility and Family Planning Survey	Use of a modern, reversible method of contraception	Living within 5 km of community-based workers	Logistic regression with a random effect	Those who live within 5 kilometers of a private practitioner who offers faimly planning increases the odds of using reversible modern contracetption by 47%.
Thang and Anh, 2002	Vietnam	1997 Vietnam Demographic and Health Survey	Non-use of a modern method	Access to any fixed service points not more than 1 km away from the community or to community workers who make home visits at least once every two weeks	Logistic regression	Women with access were 60% less likely to be nonusers.
Toroitich-Ruto, 2001	Kenya	1977/8 Kenya Fertility Survey, and the 1989 and 1993 Kenya Demographic and Health Surveys	Contraceptive use	Time taken to facility in minutes	Logistic regression	Time was insignificant
Tsui et al., 2003	Paraguay, Uganda, Tanzani, and northern India	National or large-area surveys of health facilities and households	Use of modern contraception	Distance in kilometers from nearest source of contraception	Multilevel multivariate model	Utilization of modern methods decreases as distance from services increases
Tsui, 1982	Korea and Mexico	World Fertility Survey, Korea 1974 and Mexico 1976	Contraceptive prevalence	Travel time to the nearest contraceptive source	Multiple classification analysis	Both perceived and actual accessibility to family planning can increase contraceptive prevalence and reduce unmet need.
Tuladhar, 1987	Nepal	Nepal Contraceptive Prevalence Survey, 1981	Percent of currently married, not pregnant women who know of an outlet and who are currently practicing contraception.	Travel time to nearest outlet of contraception	Cross tabulation	There is an inverse relationship between contraceptive prevalence and travel time to an outlet of contraceptives.

Author	Area of study	Data	Dependent variable	Travel-time or physical proximity variable	Method	Finding
Westoff and Bankole, 1996	Multiple	27 DHS surveys	Unmet need for contraception	Self-report that contraception is unavailable, difficult to get, or costs too much.	Cross tabulation	Lack of access is the least frequently offered reason for nonuse.