The Effect of Access to Contraceptive Services on Injectable Use and Demand for Family Planning in Malawi

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CONTEXT: *Previous studies have identified positive relationships between geographic proximity to family planning services and contraceptive use, but have not accounted for the effect of contraceptive supply reliability or the diminishing influence of facility access with increasing distance.*

METHODS: *Kernel density estimation was used to geographically link Malawi women's use of injectable contraceptives and demand for birth spacing or limiting, as drawn from the 2010 Demographic and Health Survey, with contraceptive logistics data from family planning service delivery points. Linear probability models were run to identify associations between access to injectable services—measured by distance alone and by distance combined with supply reliability—and injectable use and family planning demand among rural and urban populations.*

RESULTS: *Access to services was an important predictor of injectable use. The probability of injectable use among rural women with the most access by both measures was 7–8 percentage points higher than among rural dwellers with the least access. The probability of wanting to space or limit births among urban women who had access to the most reliable supplies was 18 percentage points higher than among their counterparts with the least access.*

CONCLUSIONS: *Product availability in the local service environment plays a critical role in women's demand for and use of contraceptive methods. Use of kernel density estimation in creating facility service environments provides a refined approach to linking women with services and accounts for both distance to facilities and supply reliability. Urban and rural differences should be considered when seeking to improve contraceptive access.*

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According to the World Bank, "Every day, nearly 800 women across the globe die due to complications during pregnancy and childbirth; 99% of these deaths occur in developing countries."[1] Although the global maternal mortality rate fell by nearly half between 1990 and 2010, this decline remains well short of the 75% reduction by 2015 set forth in Millennium Development Goal 5.[2] In Sub-Saharan Africa, where maternal mortality is highest, rates fell by 48% between 1990 and 2013.[2]

One of the most basic methods of avoiding maternal deaths is by preventing pregnancy, particularly unplanned and unwanted pregnancies.[3] For decades, family planning programs have worked to reduce the number of such pregnancies. Despite increased use of contraceptive methods, it is estimated that up to 26% of married women in Sub-Saharan Africa have an unmet need for contraception—that is, they want to delay or avoid childbearing, but are not using any method.[4] Satisfying unmet need could reduce the worldwide number of maternal deaths each year by an estimated 25–40%.[3,5] Identifying and reducing barriers of access to, and increasing the availability of, family planning services and contraceptive supplies are therefore essential.

Increasing access to family planning services encompasses improvements in the affordability, geographic proximity and quality of services provided, and improvements in all of these have been associated with increased contraceptive use.[6–9] Research has shown that the prevalence of contraceptive use within a country is directly correlated with measures of access to individual methods as well as a wider choice of method options.[8,10,11] Wang and colleagues,[8] using national-level household and health facility surveys, linked contraceptive use with availability of contraceptive products at the subnational level in East Africa, while Ngabo and colleagues[12] showed similar associations using national-level household surveys and district-level logistics data. These studies, however, focused predominantly on the ecological level and thus were not able to establish a direct relationship between individual contraceptive use and contraceptive availability in a person's service environment.

Understanding access barriers to family planning at the individual level is critical. Product satisfaction and availability are known drivers of individuals' repeat purchases.[13] The costs in time and money spent acquiring contraceptive supplies have been shown to be important determinants of contraceptive use, depending on the existing level of demand for contraception.[9] Within households, men and women apply the same rational decision making to purchasing family planning commodities as they do to other household goods; users expect to be able to buy or receive quality products when desired.[13,14] When the product is not available, consumers may decide to use

a substitute for the desired item, delay the purchase, forgo the purchase or search elsewhere. Commodity stockouts affect future consumer shopping behaviors.[15–17] In developing countries, where many family planning consumers from rural areas face long travel distances and high relative costs when seeking contraceptives, consumers who find that a clinic is out of stock are unlikely to patronize it in the future. Even in areas where contraceptives are provided to clients free of charge, a reliable supply of commodities may be an important factor in decisions about whether to seek and use family planning services.

Understanding the relationship between facility factors and a woman's choice to seek family planning services at a particular facility requires establishing a link between individual women and the individual facilities visited. Creating this link is a challenge in the absence of self-reported facility use. Connecting women with a facility requires data that include geographic coordinates for the woman's location and the facility location, which may be difficult to obtain.[18] Studies have linked individuals and clusters of households with the closest facility,[19–24] yet the implicit assumption that the nearest facility is the one used likely introduces substantial misclassification error.[25] Another common method, based on Euclidean distance measurements, has been to link a woman or household cluster with one or more facilities within a specific buffer or polygon.[8,26] While this approach may reduce the misclassification error, the size of the buffer or polygon has implications for analysis and interpretation.

Another method of operationalizing a link to services uses kernel density estimation (KDE), a spatial technique that distributes a discrete point value over a continuous surface.[27,28] KDE allows the user to consider facility attributes that may influence the use of services along with distance decay (the decline in a facility's influence on an individual's behavior as the individual's distance from the facility increases) to estimate a facility's geographic reach. KDE has been used to assess availability of health services in Nicaragua,[29] link Demographic and Health Survey household data with facility data in Rwanda[25] and evaluate access to sexual and reproductive health care in rural Mozambique.[7] The method applies an underlying assumption that a facility serves a continuous catchment area covering a certain geographic space, with higher use among those living closer to the facility. For household clusters located near multiple facilities, the overlapping catchment areas are summed, providing better representation of the total service environment.

This study builds on existing evidence for a relationship between access to contraceptives and the contraceptive prevalence rate by directly linking use of family planning methods with the availability of contraceptive supplies in the local service environment. In an effort to understand the role that facilities and product supply have on a woman's contraceptive use and demand for services in Malawi, we applied KDE to incorporate timely contraceptive supply data into our access measure. This use of routinely collected contraceptive logistics data (such as quantities of supplies dispensed monthly and monthly closing supply balances) creates a more refined estimation of the service environment available to contraceptive users.[7,25,30]

MALAWI CONTEXT

In Malawi, the family planning service environment has been developing and maturing over recent decades. The use of modern contraceptives among all women of reproductive age increased from 6% in 1992 to 33% in 2010,[31] while the maternal mortality rate fell from 1,100 to 460 deaths per 100,000 live births.[32] The most popular method reported by women using a modern one was the injectable (59%), followed by female sterilization (23%), male condoms (8%) and the pill (6%).[31]

Malawi's public sector is the dominant family planning service provider, serving 74% of all modern contraceptive users.[31] Among injectable users, 84% are served by the public sector; another 9% are seen at facilities operated by the Christian Health Association of Malawi, a nongovernmental organization that orders contraceptives and other commodities through the public-sector logistics system.[31] Women who use Depo-Provera—the injectable provided through the public sector—as their main contraceptive must visit a provider every three months for a new injection. Condoms, the pill and the injectable are provided free of charge at public health centers and hospitals and through community-based distribution agents as part of the national essential health package. In 2010, all trained providers could administer the injectable at facilities, and community agents were allowed to provide it once they had received training. As training was being scaled up in 2010, most agents had not yet been trained. Consequently, while agents are authorized to provide condoms, the pill and the injectable during door-to-door visits, the proportion of the population that received injectables from a distribution agent in 2010 was negligible.[31]

Facilities receive family planning commodities directly from regional medical stores. The supply chain management system tracks the commodities requested by and distributed to each facility. To examine the relationship between a woman's use of contraceptives and her local service environment, we focused exclusively on the injectable as the most widely used method requiring routine access to service delivery sites. Given their dominant market share for injectables, we targeted public-sector and Christian Health Association of Malawi facilities.

METHODS

Data

This analysis relied on three data sets from Malawi: the 2010 contraceptive logistics management information system data, the 2009 master health facility list and the 2010 Demographic and Health Survey.

The USAID|DELIVER PROJECT has been electronically collecting routine logistics data on contraceptive commodities at public and Christian Health Association of

Malawi health facilities in Malawi since 2008. Through use of Supply Chain Manager version 3, an open-source logistics management software package, quantities of products dispensed at each facility and the closing balance in stock are recorded monthly, which allows for the assessment of commodity availability at the end of any given month. For our analysis, we restricted the data set to health facilities that reported either having or distributing Depo-Provera anytime in 2010. In total, we identified 483 such facilities with unique identification codes.

The 2009 master health facility list identified 930 public and private health facilities by name and geographic coordinates as of that year.[33] We merged the facility file with the logistics management data to create a facility data set with coordinates. We excluded facilities if they lacked a unique identifier (234), which was typical for private facilities, or if no valid coordinates were available (125). In total, we included 571 facilities; 423 of these were injectable service delivery sites.

The 2010 Malawi Demographic and Health Survey is a national population-based household survey conducted by the National Statistical Office of Malawi and ICF Macro from June to November 2010.[31] Approximately 27,000 households participated; respondents provided information on individual and household characteristics and routine health topics, including family planning practices and use of health services. The 2010 sample was selected from the 2008 national census enumeration areas using a stratified two-stage cluster design. Locations of sampled clusters were recorded at the centroid of each cluster with global positioning system receivers. To protect survey respondent confidentiality, the survey program routinely displaces coordinates for urban and rural clusters.[34] For the 2010 survey, coordinates of urban clusters were randomly displaced up to two kilometers, and those of rural clusters were displaced up to five kilometers; for 1% of rural clusters, coordinates were displaced up to 10 kilometers. Of the total sample of 849 clusters, 827 were included in this analysis.

Dependent Variables

The two primary outcomes—current use of the injectable and demand for birth spacing or limiting—are dichotomous variables created from the woman's individual recode file from the 2010 survey. In that survey, women aged 15–49 were asked about their current contraceptive use. Those who reported current injectable use were coded as current users; those who reported either no method use or use of another reversible method (e.g., condom, the pill, traditional method, withdrawal or abstinence) were coded as nonusers of the injectable. The objective was to compare women who used the injectable with those who were potential injectable users whom a family planning program might target. We excluded individuals who reported using long-acting or permanent methods or being infecund on the basis that they were neither current nor potential users of the injectable.

The survey also asked women about their desire to have more children now or in the future. We coded women as having a demand for birth spacing or limiting if they were interested in delaying a pregnancy by two or more years or desired no more children. We coded women as not having a demand for spacing or limiting if they desired a child within the next two years, were unsure about the timing of their next pregnancy or were undecided about another pregnancy. We excluded those who reported being sterile or infecund. Women characterized as having such demand may be currently using a contraceptive or using none.

Independent Variables

We defined the independent variable—access to injectable family planning services—in two ways: distance to one or more injectable service sites based on kernel density mapping (henceforth referred to as "distance only") and a broader conceptualization that encompassed distance to one or more service sites and the reliability of injectable supplies at those sites (referred to as "distance and supply").

Constructing each access variable required linking 2010 survey clusters to health facilities from the master facility data set using kernel density estimation. We incorporated a distance decay function into the KDE, and then created a KDE surface representing access defined by distance only as follows. We defined the kernel size as 10 kilometers around every mapped facility regardless of the type of facility or location. This was based on the assumptions that visits to acquire injectable contraceptives center on product availability rather than facility type, and that urban facilities have a geographic draw for nearby peri-urban communities that is similar to the draw that rural facilities have for their communities. We set the density variable at 1 for all injectable service delivery points and at 0 for facilities that did not provide such services. We set the grid cell size at 500 meters.

Appendix Figure 1a (page 30) presents an illustration of the KDE surfaces generated for facilities 1–3. Access (shown by blue to yellow shading) is limited to a 10-kilometer diameter around each facility, with the intensity of access diminishing as one moves farther away, representing the distance decay effect. Overlapping KDE surface areas from facilities 1 and 2 show a higher intensity of service access for the combined service environment typical in an urban area. Next, we superimposed the 2010 survey clusters over the KDE surface, drawing buffers around each cluster as recommended when linking clusters to surface data.[30] We used five-kilometer buffers around urban clusters and 10-kilometer buffers around rural clusters to minimize misclassification error created by cluster displacement (Appendix Figure 1b, page 30).[25,30] We generated an average KDE value by summing the values from all pixels within the buffered area around each cluster and dividing by the total number of pixels. The average KDE values for all clusters were divided into quintiles, creating a relative access variable ranging from the least access (1)

to the most access (5).* Finally, we assigned the quintile value for each cluster to all women residing in that cluster.

We next assessed the reliability of injectable supplies for each facility. We assigned a score of 1 for a given month to facilities that had a supply of injectables available during that month. We assigned a facility a monthly score of 0.5—indicating the likely availability of the injectable—if it lacked data on its closing monthly balance, but had been dispensing stock for the month in question, the previous month and the subsequent month. A score of 0 was assigned to facilities that did not meet the foregoing criteria for any given month. We then summed the monthly scores to create a 2010 annual supply reliability score for each facility. These scores ranged from 0 to 12, with a mean of 6.25 and a median of 6.

To operationalize access as defined by distance and supply reliability, we repeated the KDE process, using the annual supply reliability score as the density variable. We then repeated all other steps, including buffering and creating a relative quintile score with the distance-and-supply-access KDE.

Analysis

Our analysis is restricted to injectable contraceptives for three reasons. First, the injectable was the most widely used method among users of modern contraceptives.[31] Second, use of the method in 2010 required quarterly visits to a health facility, making routine access an important consideration when choosing a method. Last, the link between the distribution of injectable contraceptives and actual use is assumed to be stronger than for other methods. Whereas oral contraceptives and condoms, once they are distributed, may or may not ultimately be used by the client, injectables are generally distributed by a trained health provider and "used" the moment they are distributed.

We generated descriptive statistics of the weighted study population and maps representing the two definitions of access. All spatial linking and geographic analyses were completed in ArcGIS version 10.1.

After spatially linking the sample of women to the mapped health facilities and assigning values for the two access measures on the basis of cluster location, we used the access measures in four regression models. We ran bivariate and multivariate linear probability models for each of the two outcome variables, use of injectables and demand for birth spacing or limiting. Control variables included reported exposure to media family planning messages, reported home visit in the past year from a health worker advocating family planning, desire for more children, parity, age, marital status, education, wealth, religion, rural residence and region of residence. We used weighted 2010 survey data and produced robust standard errors for all regression models using Stata SE version 12.

For each outcome variable, multivariate models were built to examine the effect of access defined by distance only and by distance and supply. We ran each model for all women of reproductive age, and stratified by rural or

TABLE 1. Selected characteristics of women aged 15-49, by rural or urban residence, Malawi Demographic and Health Survey, 2010

Characteristic	All (N= 22,483)†	Rural (N= 18,361)	Urban (N= 4,122)
Used modern contraceptive	32.6	31.7	36.8
Used an injectable	19.1	19.4	17.8
Wanted to space/limit births	70.1	70.2	69.5
Lived ≤10 km from delivery site	96.4	95.6	100.0
Access: distance only			
Least	17.8	21.4	1.9
Less	18.3	22.1	1.2
Average	20.7	24.4	3.9
More	19.3	19.6	17.7
Most	24.0	12.4	75.3
Access: distance and supply reliability			
Least	21.5	25.4	4.2
Less	18.8	21.5	7.1
Average	19.5	23.5	2.0
More	18.3	19.5	13.0
Most	21.8	10.1	73.7
Exposed to media family planning messages	59.8	58.8	64.3
Had family planning home visit in past year	13.9	15.5	6.7
Desire for more children			
In <2 years	10.6	10.4	11.4
In ≥2 years	36.4	36.2	37.5
No	42.6	42.9	41.3
Undecided	10.3	10.4	9.7
Mean no. of children	2.4	2.5	2.2
Mean age	28.0	27.2	28.2
Currently married	67.5	68.6	62.4
Education			
None	15.2	17.0	7.0
Primary	64.8	68.8	47.0
Secondary	18.2	13.6	38.7
Postsecondary	1.8	0.6	7.3
Wealth			
Lowest	18.5	22.1	2.7
Second	18.8	22.5	2.7
Middle	19.6	22.6	6.3
Fourth	19.6	20.1	17.3
Highest	23.4	12.7	71.1
Religion			
Protestant	65.1	64.5	67.6
Catholic	20.7	20.8	20.2
Muslim	13.0	13.5	11.1
Other	1.2	1.2	1.1
Region			
Northern	11.8	13.0	6.5
Central	43.5	43.2	44.5
Southern	44.7	43.8	49.0

†Data are weighted. *Notes:* All values are percentages unless otherwise indicated. Figures for percentage distributions may not total 100.0 because of rounding. The denominator for media exposure and family planning home visits is 22,476 women; that for religion is 22,469 women.

*Changes in the value of a continuous KDE variable are not readily interpretable. By creating quintiles, we considered relative access from one cluster to others. This approach is similar to that used for the Demographic and Health Survey wealth index, in which wealth quintiles are frequently used because the value itself is uninformative.

urban residence. In addition, we ran each model for married women only, because they frequently have different contraceptive intentions and patterns of use than unmarried women.

RESULTS

The 2010 Demographic and Health Survey sample used in this analysis included 22,480 women aged 15–49 from 827 mapped clusters. Eight in 10 respondents lived in a rural community. Nineteen percent of women reported current use of the injectable, 70% wanted to space or limit their births, and almost all (96%) lived within 10 kilometers of an injectable service delivery site (Table 1, page 23). Sixty percent of respondents reported media exposure to family planning messages, although only 14% had received a home visit from a family planning worker in the previous year. About a third of women wanted to wait two or more years before having another child, and four in 10 wanted no more children. Sixty-eight percent were currently married, and 85% had some schooling. Compared with rural women, urban women tended to live closer to an injectable delivery site, have fewer children, be better educated and be in a higher wealth quintile.

We mapped the potential geographic catchment area for facilities by distance only (Appendix Figure 2a, page 30) and by distance plus supply reliability (Appendix Figure 2b, page 30). The distance-only map presents the ideal scenario if all facilities had a reliable monthly supply of injectables. The distance-and-supply map presents a picture of service access once supply reliability is taken into account. A comparison of the two maps shows areas with potential gaps in service access, such as the Central Region, where the injectable supply was less reliable.

In both multivariate regression models, access to injectable service delivery sites was a positive predictor of injectable use in the total sample of women (Table 2). The probability of using injectables, when considering distance only, was 5.6 and 5.7 percentage points higher, respectively, among women with more access and the most access to delivery sites than among those with the least access, when controlling for all other variables. Similarly, when considering access based on distance and supply reliability, the probability of using injectables was 3.3–5.2 percentage points higher among women with average, more and the most access to services than among those with the least access. Other predictors in the full models demonstrated expected results, with desire for more children, higher parity, increasing age and being married all associated with a woman's choice to use the injectable (not shown). Compared with women living in the Northern Region, those in the Central and Southern Regions were more likely to use injectables. The second outcome, demand for birth spacing or limiting, was associated with access only among those in the highest access quintile: The likelihood of such demand was 4.1–4.3 percentage points higher among these women.

In analyses that stratified the population by rural and urban residence, we found that the relationship between access and injectable use strengthened for women in rural communities, while it disappeared for urban women (not shown). In contrast, the association between distance-and-supply access and demand for spacing or limiting births among urban women was substantial, but this relationship disappeared among rural women. Given these results, we focused on the full models for access and injectable use in rural areas, and for access and family planning demand in urban areas.

The probability of injectable use among rural women with the best distance-and-supply access was 7.5 percentage points higher than among their counterparts with the least access (Table 3, page 25). Exposure to demand-generation activities, such as media messaging and home visits from a family planning worker in the past year, had mixed results: Home visits were associated with significantly greater use (by 3.2 percentage points), while media exposure to family planning messages was not. Women's desire for spacing or limiting births, as well as increasing parity, were positively associated with injectable use. Other significant variables included age, marital status, education, wealth and region.

The probability of having a demand for birth spacing or limiting among urban women with the most distance-and-supply access was 18.3 percentage points higher than among those with the least access (Table 4, page 26). The

TABLE 2. Coefficients (and standard errors) of the estimated effect of access to services on women's reported injectable use and demand for spacing or limiting births, by access measure, for the entire sample and stratified by rural and urban residence

Characteristic	Injectable use		Demand for spacing/limiting	
	Access: distance	Access: distance+supply	Access: distance	Access: distance+supply
ALL	(N=20,158)	(N=20,158)	(N=20,413)	(N=20,413)
Access				
Least (ref)	na	na	na	na
Less	0.018 (0.013)	0.021(0.012)	0.003 (0.014)	0.014 (0.013)
Average	0.027 (0.014)	0.033 (0.012)**	0.001 (0.014)	0.006 (0.013)
More	0.056 (0.014)***	0.044 (0.014)**	0.004 (0.014)	0.019 (0.014)
Most	0.057 (0.015)***	0.052 (0.015)***	0.041 (0.016)*	0.043 (0.017)*
Pseudo R^2	*0.161*	*0.160*	*0.148*	*0.148*
RURAL	(N=16,536)	(N=16,536)	(N=16,680)	(N=16,680)
Access				
Least (ref)	na	na	na	na
Less	0.020 (0.013)	0.021 (0.013)	0.001 (0.014)	0.008 (0.013)
Average	0.027 (0.015)	0.035 (0.012)**	0.002 (0.014)	0.000 (0.014)
More	0.048 (0.014)**	0.045 (0.014)**	–0.001 (0.014)	0.012 (0.015)
Most	0.072 (0.015)***	0.075 (0.016)***	0.035 (0.016)*	0.021 (0.017)
Pseudo R^2	*0.156*	*0.156*	*0.155*	*0.154*
URBAN	(N=3,622)	(N=3,622)	(N=3,733)	(N=3,733)
Access				
Least (ref)	na	na	na	na
Less	–0.074 (0.027)**	–0.006 (0.037)	0.049 (0.143)	0.140 (0.062)*
Average	–0.073 (0.038)	0.050 (0.034)	0.026 (0.144)	0.128 (0.066)
More	–0.010 (0.027)	–0.005 (0.032)	0.100 (0.145)	0.133 (0.056)*
Most	–0.040 (0.019)*	–0.011 (0.028)	0.133 (0.144)	0.183 (0.053)**
Pseudo R^2	*0.208*	*0.207*	*0.142*	*0.145*

*p<.05. **p<.01. ***p<.001. *Notes:* All models controlled for exposure to media family planning messages, home visit from a health worker advocating family planning, desire for more children, parity, age, marital status, education, wealth, religion and region of residence. ref=reference group. na=not applicable.

association between access and demand was not evident when access was defined by distance only. Whether access was defined by distance or by distance and supply, women who reported a family planning home visit were more likely than others to want to space or limit births (by 7.4 and 6.8 percentage points, respectively). Other significant predictors of demand included parity, age, education and region. Marital status and wealth were not associated with spacing or limiting demand among urban women. When we restricted the regression to married women, we found similar results (not shown).

DISCUSSION

The dynamics between access and injectable use and between access and desire for spacing or limiting births are different in urban and rural environments. In our models, access to injectable services in the local environment was associated with a higher probability of rural residents using the method, confirming the important role that service availability plays in contraceptive use in developing countries.[7,8,19,35] However, measuring access by distance and reliability of injectable supplies did not improve on the distance-only access model for the rural population, which suggests that in rural environments, inconvenient distance is more salient in limiting use than lack of reliable supplies. The predictive effect size of distance-only access among rural women was comparable to the effect size seen with improving education, increasing wealth or receiving a family planning home visit. These results suggest that programs designed to improve rural women's proximity to family planning services, including expanding the use of community-based distribution agents, the number of service locations and the provision of services through the private sector, are practical methods of improving family planning use from a health system perspective.

No association was found between either access measure and injectable use among urban women in any of the access quintiles. This may be attributable to the existence of more homogeneity across access categories in the urban service environment. The assignment to quintiles for the access variables was performed with the total sample of clusters to create the two access variables for the entire country. When we focused on urban women, we found that the vast majority had average or better access (the top three quintiles), and all lived within 10 kilometers of an injectable service delivery site. In an urban environment where proximity is less of a barrier, other factors play a larger role in predicting use. These findings reinforce recommendations to look deeper into rural versus urban differences to better understand population and health outcomes.[36]

Our findings relating access to demand for birth spacing or limiting tell a different story. Among rural women, access to injectable services had no measurable relationship with spacing or limiting births. This was not an entirely surprising outcome; availability of contraceptives may not be adequate to generate demand. Rather, programs to increase demand for limiting family size or spacing births

TABLE 3. Coefficients (and standard errors) of the estimated effect of access to services on rural women's reported injectable use, by access measure

Characteristic	Access: distance	Access: distance+supply
Access		
Least (ref)	na	na
Less	0.020 (0.013)	0.021 (0.013)
Average	0.027 (0.015)	0.035 (0.012)**
More	0.048 (0.014)**	0.045 (0.014)**
Most	0.072 (0.015)***	0.075 (0.016)***
Exposed to media family planning messages	0.013 (0.008)	0.013 (0.008)
Had family planning home visit in past year	0.033 (0.012)**	0.032 (0.012)**
Desire for more children		
In <2 years (ref)	na	na
In ≥2 years	0.113 (0.013)***	0.113 (0.013)***
No	0.076 (0.013)***	0.076 (0.013)***
Undecided	0.067 (0.014)***	0.066 (0.014)***
Parity		
0 (ref)	na	na
1–2	0.218 (0.012)***	0.218 (0.012)***
3–4	0.314 (0.015)***	0.313 (0.015)***
≥5	0.351 (0.018)***	0.350 (0.018)***
Age		
15–19 (ref)	na	na
20–24	0.007 (0.013)	0.007 (0.013)
25–29	–0.005 (0.018)	–0.005 (0.018)
30–34	–0.071 (0.020)***	–0.070 (0.020)***
35–39	–0.100 (0.020)***	–0.098 (0.020)***
40–44	–0.194 (0.022)***	–0.192 (0.022)***
45–49	–0.275 (0.019)***	–0.273 (0.019)***
Marital status		
Married (ref)	na	na
Formerly married	–0.130 (0.011)***	–0.129 (0.011)***
Never-married	–0.092 (0.012)***	–0.091 (0.012)***
Education		
None (ref)	na	na
Primary	0.031 (0.011)**	0.031 (0.011)**
Secondary	0.030 (0.015)	0.031 (0.015)*
Postsecondary	0.009 (0.043)	0.009 (0.043)
Wealth		
Lowest (ref)	na	na
Second	0.025 (0.012)*	0.025 (0.012)*
Middle	0.032 (0.011)**	0.032 (0.011)**
Fourth	0.043 (0.012)***	0.043 (0.011)***
Highest	0.030 (0.014)*	0.029 (0.014)*
Religion		
Protestant (ref)	na	na
Catholic	–0.003 (0.010)	–0.003 (0.010)
Muslim	–0.071 (0.011)***	–0.067 (0.011)***
Other	–0.068 (0.038)	–0.062 (0.037)
Region		
Northern (ref)	na	na
Central	0.086 (0.014)***	0.106 (0.014)***
Southern	0.093 (0.014)***	0.100 (0.014)***
Constant	*–0.156 (0.021)****	*–0.169 (0.021)****
Pseudo R^2	*0.156*	*0.156*

*p<.05. **p<.01. ***p<.001. *Notes:* ref=reference group. na=not applicable.

TABLE 4. Coefficients (and standard errors) of the estimated effect of access to services on urban women's reported demand for spacing or limiting births, by access measure

Characteristic	Access: distance	Access: distance+supply
Access		
Least (ref)	na	na
Less	0.049 (0.143)	0.140 (0.062)*
Average	0.026 (0.144)	0.128 (0.066)
More	0.100 (0.145)	0.133 (0.056)*
Most	0.133 (0.144)	0.183 (0.053)**
Exposed to media family planning messages	–0.017 (0.024)	–0.011 (0.024)
Had family planning home visit in past year	0.074 (0.029)*	0.068 (0.029)*
Parity		
0 (ref)	na	na
1–2	0.317 (0.037)***	0.318 (0.037)***
3–4	0.541 (0.045)***	0.537 (0.044)***
≥5	0.592 (0.044)***	0.591 (0.043)***
Age		
15–19 (ref)	na	na
20–24	–0.084 (0.035)*	–0.086 (0.034)*
25–29	–0.226 (0.044)***	–0.231 (0.044)***
30–34	–0.312 (0.040)***	–0.315 (0.039)***
35–39	–0.268 (0.051)***	–0.267 (0.051)***
40–44	–0.155 (0.045)**	–0.157 (0.045)**
45–49	–0.149 (0.047)**	–0.152 (0.046)**
Marital status		
Married (ref)	na	na
Formerly married	–0.001 (0.025)	–0.004 (0.025)
Never-married	0.025 (0.043)	0.021 (0.043)
Education		
None (ref)	na	na
Primary	0.019 (0.044)	0.014 (0.043)
Secondary	0.084 (0.052)	0.076 (0.050)
Postsecondary	0.136 (0.066)*	0.122 (0.064)
Wealth		
Lowest (ref)	na	na
Second	0.025 (0.076)	0.015 (0.071)
Middle	–0.047 (0.063)	–0.047 (0.061)
Fourth	–0.074 (0.056)	–0.076 (0.054)
Highest	–0.042 (0.056)	–0.048 (0.054)
Religion		
Protestant (ref)	na	na
Catholic	–0.002 (0.024)	–0.005 (0.024)
Muslim	–0.035 (0.027)	–0.039 (0.027)
Other	0.034 (0.092)	0.030 (0.092)
Region		
Northern (ref)	na	na
Central	0.098 (0.038)*	0.114 (0.034)**
Southern	0.079 (0.039)*	0.087 (0.034)*
Constant	*0.420 (0.157)***	*0.377 (0.086)****
Pseudo R2	*0.142*	*0.145*

*p<.05.**p<.01.***p<.001. *Notes:* ref=reference group. na=not applicable.

through education and outreach remain a necessary complement to efforts to increase access to contraceptives in rural communities.

A more surprising finding was the strong association between access and desire for birth spacing or limiting in the urban environment. However, this relationship was found only for the distance-and-supply access variable. The effect size for women with the greatest distance-and-supply access was larger than that attributed to increased education or reception of family planning home visits. Because our analysis used Demographic and Health Survey data with only one time point, we were unable to tease out the direction of this relationship. For example, we cannot determine whether better access to a reliable injectable supply influenced urban women's desire for birth spacing or limiting, or whether facilities in communities with higher demand for family planning prioritized having a reliable supply to better serve their clients. One explanation is that a reliable supply at an urban facility may increase the demand for spacing or limiting births, possibly by influencing neighborhood norms in urban communities. Alternatively, communities with perceived high demand for family planning may have been prioritized for supply chain improvements; hence, a reliable supply is already available to meet demand. Understanding the motivations of and deterrents to family planning use in urban environments remains a challenge given the usual data relied on for analyses.

Our use of kernel density estimation and focus on contraceptive supply logistics also reveal substantial gaps in supply reliability and illustrate the ideal scenario if supply were constant. These maps suggest potential geographic priority areas for supply chain improvements in Malawi, such as the Central Region, which suffered from unreliable supply.

As noted earlier, when assessing supply reliability, incomplete facility reporting required certain assumptions (based on field experience) that may have led to some over- or underestimation. Moreover, our analysis excluded private sites and dropped public sites with missing geographic coordinates; these omissions have two potential consequences. The exclusion of private facilities may have resulted in omitted variable bias, which may have biased our results for the urban analyses; however, because most injectable users rely on public-sector supplies, the threat to our estimates is believed to be low. Analysis of the 60 excluded public facilities found comparable routine stockout rates across both included and excluded facilities, as well as an equivalent distribution of dropped facilities across districts. We cannot assume that facilities were missing at random, however, because the health centers excluded because of missing geographic coordinates were more likely to have smaller injectable supplies, and this may introduce limited bias into our estimates.

We should also note how well the measurements of access were operationalized. In the absence of survey data on the specific facilities used, it would be unwise to link women with the closest facilities, and linking with large administrative units may distort or mask potential relationships.[7,8,25,30,35,37] Because we used a census of facilities providing injectables to create a service environment using KDE with distance decay properties, and then averaged KDE values for a buffered area around each survey cluster, we were able to link women to all the injectable facilities in their service environment, thereby minimizing misclas-

sification error.[25,30] In generating the local service environments, the KDE method distributes facility reach such that a facility has less influence on an individual's behavior the farther the individual lives from the site. Moreover, KDE allows the researcher to include other facility characteristics—in our case, supply reliability—that are deemed influential in an individual's decision to visit a facility.

Finally, our study matched, in time and location, routinely collected contraceptive supply data from a census of facilities with population-based household survey data on injectable use and desire for birth spacing or limiting. Previous studies have used a more nuanced service quality score based on a variety of measures of facility, provider and service availability,[7,8,38] but relied on measurement at a single point in time. An exploration of methods to combine the richness of facility survey data with the timeliness of supply logistics data may eliminate the trade-off between breadth and depth, providing a fruitful avenue for further study.

Conclusions

Kernel density estimation enabled us to create a refined definition of access to a family planning service environment that incorporates measures of service availability, proximity and contraceptive supply reliability. This allowed us to probabilistically link a woman's injectable use and desire for spacing or limiting births with her available local services. Future research could apply this methodology to other family planning commodities provided by the health care sector.

Our findings add to the growing body of evidence illustrating the importance of a robust contraceptive supply chain and product availability in the local service environment and their relationships with use of and demand for modern contraceptives. We found that among rural women, reported use of injectables was strongly associated with access to services, defined both by distance alone and by distance and supply reliability. In urban settings, demand for birth limiting or spacing was positively associated with distance-and-supply access, while distance alone was not correlated with use or demand. These findings reinforce the need to address rural and urban population and service environment differences to improve health outcomes. Moreover, given the rise in private-sector family planning providers and community-based distribution alternatives, exploring their differential effects on urban and rural environments in future analyses may provide useful knowledge about the factors influencing family planning uptake. As the global community continues working to reduce maternal mortality and strengthen reproductive health services, further research is needed to capture and clarify the causal pathways between contraceptive access and use.

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RESUMEN

Contexto: *Estudios previos han identificado relaciones positivas entre la proximidad geográfica a los servicios de planificación familiar y el uso de anticonceptivos, pero no han dado cuenta del efecto de la confiabilidad del suministro de anticonceptivos o de la influencia decreciente que tiene el acceso a las instituciones de salud a medida que la distancia aumenta.*

Métodos: *Se usó el método de estimación de densidad de kernel para vincular geográficamente el uso de anticonceptivos inyectables por parte de mujeres de Malaui y la demanda de espaciamiento o limitación de sus embarazos, combinando datos obtenidos de la Encuesta Demográfica y de Salud de 2010, con datos de logística de anticonceptivos provenientes de los puntos de prestación de servicios de planificación familiar. Se usaron modelos de probabilidad lineal para identificar las asociaciones entre el acceso a servicios que proveen métodos inyectables–medido por la distancia solamente y por la distancia combinada con la confiabilidad del suministro–y el uso de inyectables, y la demanda de planificación familiar en poblaciones rurales y urbanas.*

Resultados: *El acceso a los servicios fue un factor importante de predicción del uso de inyectables. La probabilidad de usar inyectables entre las mujeres que viven en áreas rurales con el mayor nivel de acceso en ambas medidas fue 7–8 puntos porcentuales más alta que entre las habitantes de zonas rurales con el menor nivel de acceso. La probabilidad del deseo de espaciar o limitar sus embarazos entre las mujeres de zonas urbanas que tenían acceso a los suministros más confiables fue 18 puntos porcentuales más alta que entre sus contrapartes con el menor nivel de acceso.*

Conclusiones: *La disponibilidad de productos en el entorno de los servicios locales juega un rol esencial en la demanda de métodos anticonceptivos y en su uso por parte de las mujeres. El uso del método de estimación de densidad de kernel para crear entornos de servicio en instituciones de salud ofrece un enfoque refinado para vincular a las mujeres con los servicios, y toma en cuenta tanto la distancia a las instituciones de salud como la confiabilidad de los suministros. Las diferencias entre los medios urbano y rural deben considerarse cuando se busque mejorar el acceso a los anticonceptivos.*

RÉSUMÉ

Contexte: *Les études antérieures ont identifié les rapports positifs entre la proximité géographique des services de planification familiale et la pratique contraceptive, sans toutefois rendre compte de l'effet de la fiabilité de l'offre contraceptive ou de la moindre influence de l'accès aux structures quand la distance augmente.*

Méthodes: *L'estimation par noyau a servi à lier géographiquement le recours des femmes du Malawi à la contraception injectable et leur demande d'espacement ou de limitation des naissances, d'après l'Enquête démographique et de santé de 2010, aux données logistiques contraceptives des points de prestation de services de planification familiale. Les associations entre l'accès aux services de l'injectable – mesuré en fonction de la distance seule et en fonction de la distance combinée à la fiabilité de l'offre – et la pratique de l'injectable et demande de planification familiale parmi les populations urbaines et rurales ont été identifiées au moyen de modèles de probabilité linéaire.*

Résultats: *L'accès aux services est un prédicteur important de recours à l'injectable. La probabilité du recours à la méthode parmi les femmes des milieux ruraux disposant du meilleur accès selon les deux mesures est de 7 à 8 points de pourcentage supérieure à celle observée parmi les résidentes rurales disposant du moindre accès. La probabilité du désir d'espacement ou de limitation parmi les femmes urbaines disposant de l'accès à l'offre la plus fiable est de 18 points de pourcentage*

supérieure à celle obtenue pour leurs homologues bénéficiant du moindre accès.

Conclusions: *La disponibilité du produit dans l'environnement de prestation local joue un rôle essentiel dans la demande et la pratique contraceptive des femmes. L'estimation par noyau pour la création d'environnements de prestation procure une approche plus fine de liaison des femmes aux services tout en rendant compte de la distance aux structures et de la fiabilité de l'offre. Les différences urbaines et rurales doivent être considérées dans la recherche d'amélioration de l'accès à la contraception.*

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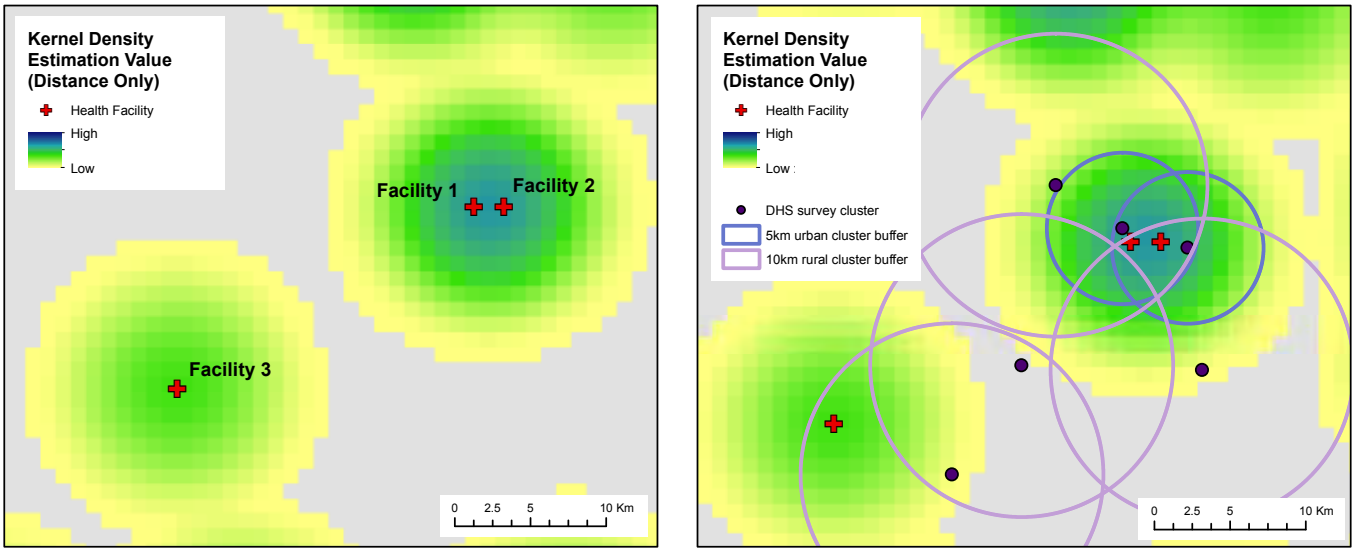
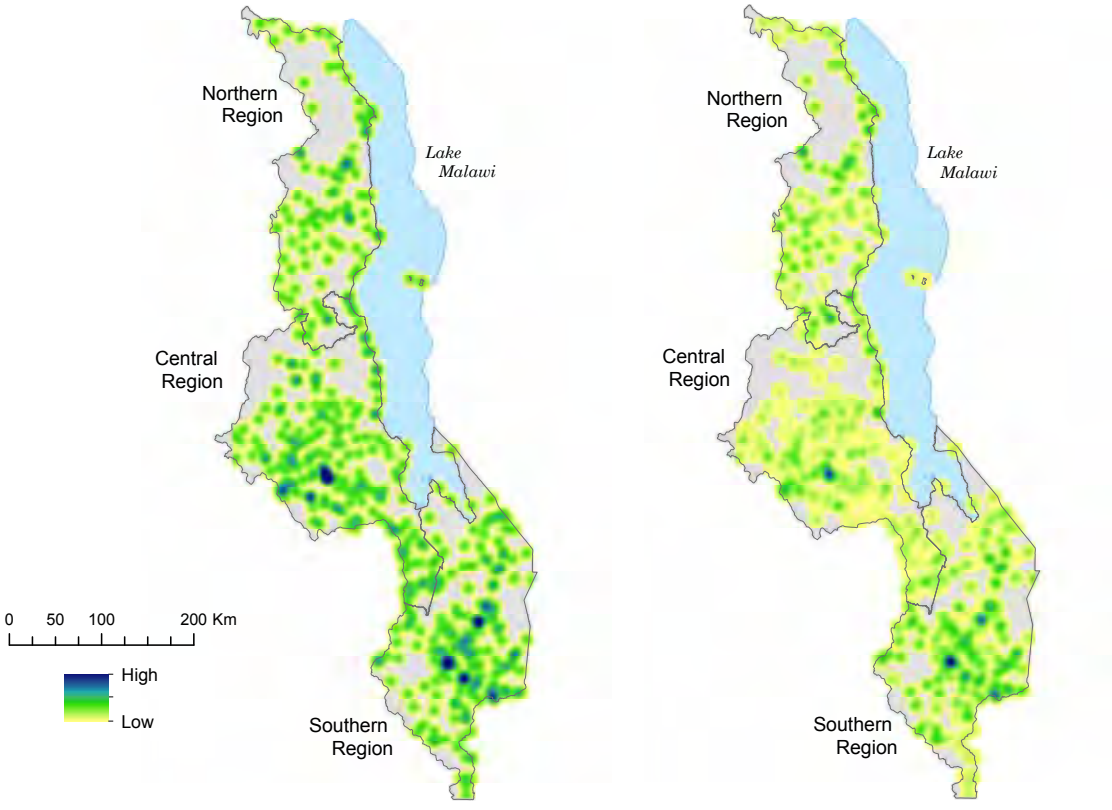
APPENDIX FIGURE 1. Illustration of kernel density estimation with sample facilities and survey clusters



a. Facility KDE **b. Facility KDE with survey clusters**

APPENDIX FIGURE 2. Access to injectable services represented using kernel density estimation, by distance only and by distance plus supply reliability



a. Distance only **b. Distance and supply reliability**