TITLE

UNDERSTANDING MODERN CONTRACEPTIVE SUPPLY DYNAMICS: A LATENT CLASS ANALYSIS OF THE CM4FP PROJECT'S LONGITUDINAL OUTLET DATA FROM NIGERIA

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ABSTRACT

Understanding FP supply is important for ensuring access to FP products, and yet relatively little is known about FP supply-side dynamics. Other studies have used cross-sectional, point-in-time data collected from samples of FP outlets to explore this question, and have found relatively stable FP supply at aggregate level. Using three rounds of longitudinal data from a census of FP outlets collected quarterly by the CM4FP project between 2019 and 2020 in Nigeria, we explore whether market dynamics look different when analyzed at outlet level over time and use latent class analysis to explore underlying patterns in availability and stock out across six main FP products between census rounds

We found that FP products went in and out of stock more frequently than data at aggregate level suggests. Our analysis of individual products suggests outlets change stocking status for short-acting methods and emergency contraception (EC) more commonly than long-acting reversible contraceptives. Using latent class analysis we propose a three-class model for FP product availability as a good fit for identifying unobserved outlet groupings in the data. Likelihood of class membership varied by outlet type, with smaller private sector outlets most likely to be classified as having primarily short acting methods available and larger facilities as having all non-EC methods available. Transition between classes was most likely for outlets whose base class membership showed limited method availability.

These results have two main implications. First, FP product supply may be more dynamic than we thought, but detecting these changes in availability and stockout requires following outlets over time. Second, latent class analysis provides us with an alternative, parsimonious way to characterize outlets according to their FP method availability or stockout status that is potentially less arbitrary than measures that focus just on outlets having 3+ or 5+ FP methods available.

KEYWORDS

Family planning supply; contraception; market dynamics; panel data; latent variable models

What is already known?

- The majority of family planning (FP) studies to date have focused on demand-side factors
- Understanding FP product supply is an essential element in ensuring access for consumers to that they can freely decide the number and spacing of their children
- Previous studies on the supply side have tended to only sample certain types of FP outlet, using cross-sectional data, and relying on descriptive statistics, and suggest FP supply looks relatively stable at aggregate level

What are the new findings?

- Outlets go in and out of stock for individual FP products much more commonly than previous aggregate level data suggested
- Using latent class analysis, we have characterized outlets providing FP in the study sites in Nigeria as having three main types based on FP product availability and stockout
- The latent class of an outlet is generally quite stable over 9-month period analyzed here, meaning that those classified in the *short-acting methods* class are very likely to remain there, those in the *all non-EC methods*, likewise. Only outlets in the *limited method availability* state were more likely to move to another class over time.

What do the new findings imply?

- Methodologically speaking, understanding the FP supply side requires data on the total market for FP, including small private sector providers that may be excluded from facility studies, but that make up a large and stable part of the market, while tracking change over time at outlet level gives a much more nuanced view of what is happening

- Using the data-driven classifications for outlets (*Limited method availability*, *Short-acting methods*, and *All non-EC methods*) offers an alternative way to characterize the FP supply side that may prove less arbitrary that indicators such outlets with *3+ or 5+ methods available*, as commonly used for FP tracking.
- Further work is needed to better understand the drivers of outlet supply dynamism, and what effect it has on consumers' experience of the FP market

INTRODUCTION

FP supply is an important component for ensuring access to FP products, and yet relatively little is known about FP supply-side dynamics. Recent efforts to capture FP product availability dynamics have relied on approaches that can only give a picture at aggregate level [1] while many FP market analyses have only cross-sectional data.[2] Understanding outlet-level change over time is a critical piece of the supply side puzzle, arguably especially relevant for populations in growing urban, peri-urban, and semi-urban areas in LMICs that are characterized by complex FP markets with a range of public and private sources of contraceptive access.[3,4] In this paper, we investigate what longitudinal data on the total FP market can tell us about dynamics obscured by aggregate point-in-time data from outlet samples.

Using three rounds of quarterly outlet census data on the total market for FP products from four study sites in Nigeria, we measure the extent to which FP product availability and stocking status varied within study sites and within individual outlets over a nine-month period. This study aims to deepen understanding of the market dynamics of contraceptive products using latent class analysis, an approach that we believe to be novel in the analysis of contraceptive supply-side data. Latent class analysis is a data-driven approach that produces typologies of FP product supply, availability, and stockout at the outlet level, where changes in these can be tracked over time. Such evidence is critical for understanding the actual markets for FP supply, contraceptive accessibility, and coverage over time.

BACKGROUND

Access to FP and variability in supply

Ensuring access to high-quality, voluntary family planning (FP) services and a range of contraceptive methods is essential for providing women, girls, and their partners with the opportunity to realize their reproductive choices and autonomy.[5] Despite investments in strengthening FP markets, progress has been slow in some regions [6,7] and lack of access accounts for a substantial minority of contraceptive non-use among women of reproductive age in West and Central Africa; cited by 18% of women in Nigeria.[8] Previous studies have identified persistent supply chain challenges resulting in contraceptive stockouts in LMICs, most notably affecting public facilities in rural areas.[9,10] A primary goal of the global FP community is to ensure access to a stable supply of affordable, high-quality contraceptive options. Despite this, there is relatively little evidence describing longitudinal changes in product availability over time within specific FP outlets.[9]

The existing FP literature highlights extensive variation in method availability by outlet type, contraceptive method, and country.[1,11–14] However, temporal variation in contraceptive product availability and stockout across repeated cross-sectional assessments aggregated to regional level was found to be relatively low in one multi-country analysis using PMA data [1] suggesting that contraceptive users are unlikely to experience access barriers that are specifically related to unpredictability of product availability.

In many LMIC markets, private sector contraceptive-supplying outlets, and in particular pharmacies, are more numerous than public sector outlets, but often offer a smaller range of methods,[1,11–13,15] and tend to be underrepresented in surveys. In Nigeria, outlet types that provide contraceptives generally include hospitals, health clinics, health centers, pharmacies, PPMVs (Patent and Proprietary Medicine Vendors), CHWs and drug shops, both in the public and private sectors. Products offered vary by outlet type: hospitals and clinics can generally offer a full range of products while policies tend to restrict pharmacies and lower-level outlets to short-acting methods, with the private sector tending to predominate.[16,17] Existing evidence from sub-Saharan Africa, reliant on cross-sectional data, suggests that stockouts of individual FP products are quite common and that availability and stockouts vary by outlet and product type,[1,11,12,15,18] even when the number of FP stocking outlets was quite stable.[15] A multicounty analysis of PMA data suggests that for most products and countries analyzed, the proportion of outlets with a given product available was relatively stable between quarterly survey rounds.[1] However, the existing literature has tended to rely on cross-sectional samples of outlets, and frequently reports aggregated results. Being able to track the total FP market longitudinally at outlet level might provide a more comprehensive view of supply-side dynamism.

Evidence gap

While approaches to monitoring contraceptive availability have expanded and improved over time, gaps remain in our understanding of the dynamism of the FP market. Existing evidence on FP availability and stockout relies on cross-sectional outlet data that does not capture the extent to which stock supply varies at the outlet level. These data tend to use samples that often exclude or underrepresent smaller private sector outlets, which means they cannot give a view of the total market for contraceptive products in a given geographical area.

This paper aims to contribute to our understanding of contraceptive supply-side dynamics by examining change in contraceptive product availability and stockout at outlet level over time., going beyond previous work that has focused on aggregate level change. Analyzing novel data from a census and longitudinal panel of FP outlets, we examine within-outlet patterns of stocking and availability using latent class analysis, a data driven approach to characterizing FP product stocking patterns, providing a new perspective on FP supply side market dynamics.

METHODOLOGY

Study design

This study uses data collected through the Consumer's Market for Family Planning (CM4FP) study, implemented by Population Services International (PSI) and funded by the Bill and Melinda Gates Foundation. CM4FP conducted a census of all outlets that offer contraceptive products or services (beyond only male condoms) in four study sites in each of Kenya, Nigeria, and Uganda. The sites were purposively selected and located in urban areas. Study rounds were repeated on a quarterly basis. The study was not designed to provide representative estimates at the national, regional, or municipal level, nor is it representative of the overall urban areas in which its sites were located, but rather it provides in-depth localized FP market data. In total, the study included 664, 672 and 500 outlets[1] and 3,816, 4,729, and 2,991 women in Kenya, Nigeria and Uganda, respectively. We provide a brief overview of the study design and methods here but details have been described on the CM4FP website (www.cm4fp.org) and elsewhere (Conlon et al., forthcoming).

Ethical approval

The study protocol and procedures were approved by PSI's Research Ethics Board (#04.2018.). Nigerian study procedures were approved by the National Health Research Ethics Committee of Nigeria (NHREC/01/01/2007-27/05/2019).

Patient and public involvement in research

This study does not include patient populations. The data presented here pertain to FP outlets only. All data and study documentation however are freely available to the public on the CM4FP project website.

Data sources and description of key variables

CM4FP data were collected in three quarterly surveys in 2019 and 2020.[2]. Four study sites were selected with varied levels of urbanity that ranged from large urban to peri-urban. CM4FP employed a similar methodology to the FPwatch study,[19] but expanding the approach to include longitudinal data collection. During each survey round enumerators conducted a census of all reproductive health-related outlets, which included hospitals, health facilities, pharmacies, drug shops, and other facilities with a current or history of stocking at least one contraceptive type beyond male condoms.

All modern contraceptive product types were captured in the product audit during the outlet census. Our analysis here focuses only on those that were most commonly available, which make up the overwhelming majority of contraceptive products captured in the survey (93% in the Nigeria round 1 data, for example) and corresponds to the main categories captured in most contraceptive data sources: male condoms, oral contraceptive pills, emergency

[1] Data for Community Health Workers (CHWs) are only present for Nigeria in rounds 1 and 2 and Kenya and Uganda in round 1. As these contraceptive product providers are not present in all census rounds, we exclude them from our analysis.

[2] The onset of the COVID-19 pandemic disrupted the final round of data collection, truncating outlet data collection from a planned 4 to 3 quarterly surveys.

contraceptive pills, injectables, implants, and copper IUDs. For injectables (where one-, two-, and three-month varieties are available), and implants (where three-, four-, and five-year varieties are available), we have pooled varieties together as "injectables" and "implants" in our analysis, respectively.

Four categories of stock status are present for each product type within each outlet: 1) currently in stock, where at least one brand of the product type was available to consumers, with no stockout history in the previous three months, 2) currently in stock *with* a stockout recorded in the previous three months, 3) currently stocked out, where no brand of the product type was available to consumers on the day of the audit when otherwise available at some point in the previous three months, and 4) not offered at this outlet, where no brand of product type was available to consumers at any point in the previous three months.

Change in availability, where a contraceptive has been stocked within the previous three months, or in-stock status, where a contraceptive has been stocked within the previous three months and is currently in stock, between rounds was captured by three categories: no change in availability or stock status, change from stockout/unavailable to in stock, and change from in stock to stockout/unavailable. The inter-round periods from round 1 to round 2 and from round 2 to round 3 were covered by these categories.

Outlets were also categorized by managing authority and facility type. In the round when an outlet was first included in the census, outlets were identified on if they fell under a government or private managing authority. Enumerators identified the facility type upon visiting and confirmed their observations with staff during interviews. Facility types included hospitals, health facilities, health clinics, pharmacies, and patent and proprietary medicine vendors (PPMV)/drug shops, and others.

Data analysis

We restricted our analysis presented here to the three quarterly rounds of outlet data collection from Nigeria, where the number of outlets with a change in stock status was greatest among study countries, and where results are aggregated, we present them at the study site level.

As a first step, we measured product availability, stockout, and history of stockout for each product type, at the outlet level, for each round of data collection in the Nigerian study sites (results for Kenya and Uganda are presented in the supplemental materials). Aggregate offering/availability/stockout measures for each product type were measured at the study site level for each of the three rounds. Change over time was analyzed descriptively. At the aggregate level, we present the relative percentages of outlets with different methods available or unavailable on the day of survey over time. At the outlet level we present the percentage of outlets that switched categories from available to stockout/unavailable for each method type, and vice versa, between rounds.

As a second step, to investigate the overall patterns in change of the availability and stockout status of contraceptive methods, we pooled the data across all three rounds and conducted latent class analysis[3]. Latent class analysis enables the categorization of outlets into similar classes using unobserved characteristics explained by observed data. In this context, availability of contraceptive methods may identify groupings of outlets where stock status of these methods is similar to those within the same identified class and different from outlets in separate classes. Importantly, these grouping emerge naturally from the data and are not prescribed a priori. We built latent class models which were specified as follows:

$$P(\boldsymbol{Y} = \boldsymbol{y}) = \sum_{c=1}^{C} \gamma_C \prod_{j=1}^{6} \prod_{r_j=1}^{3} \rho_{j,r_j|c}^{I(y_j=r_j)} \qquad (1)$$

c represents a latent class which an outlet belongs to, γ_C represents the probability of this class membership, j represents a contraceptive method (j=1…6; male condoms, OCP, etc.), and r_j represents an availability status (1=not offered, 2=stockout, and 3=available) of method j in the outlet. $I(y_j = r_j)$ is an indicator function that leads to a particular combination of availability status and contraceptive methods. $\rho_{j,r_j|c}$ denotes the probability of a contraceptive method j with an availability status r_j, conditional on a class membership c.

For each outlet in our final class model, we calculated from its posterior probabilities of belonging to different classes, $P(L = c|\boldsymbol{Y} = \boldsymbol{y})$, and assigned it to the class with the largest posterior probability. We used the classification results to track how outlets moved from one class to another over time and calculated a transition matrix of stockout and availability from round 1 to 2 and from round 2 to 3, respectively. We present descriptive statistics of the characteristics of outlets in each class and transitioning between classes.

RESULTS

Stock status of contraceptive products among outlets shows different patterns across sites in Nigeria and by product type. However, for any given study site and contraceptive product type, aggregate level availability/stockout measures tended to underestimate the amount of outlet-level change in contraceptive product availability/stockout change between study rounds, in particular for short-acting contraceptives and EC (Figure 1 and Table S1). For example, in the large urban site in Nigeria (Lagos), 46.4% of outlets had OCP in stock in round 2 at the aggregate level and this remained stable (47.8%) in round 3. However, 28% of outlets changed their stocking status for OCP during the interval between these two time points, meaning that stability in aggregate reporting of stock availability masks substantial shifts in status among individual outlets. Similar numbers of outlets went from having OCP available to unavailable, and from unavailable to available, changes that are not captured by stability at the aggregate level. The same pattern was seen in the small urban site (Abia), with aggregate OCP availability staying almost constant between rounds 1, 2 and 3 (with 77%, 76% and 76% of outlets having OCP available, respectively),

[3] For this analysis, the two in-stock categories were collapsed into a single "currently in stock" condition so that the stock status for each method has three categories.

while 24% of outlets went from stockout to available or vice versa between rounds 1 and 2, and 20% changed status between rounds 2 and 3.

Latent classes for Nigeria data

Latent class analysis is a type of latent variable analysis that allows FP outlets to be classified according to patterns in their availability of FP methods, with the classes identified from the data itself rather than according to a priori assumptions. Three classes were identified through the latent class model, based on the stocking status across all product types (Figure 2). The first class identifies outlets with low availability of all methods, which we interpret and label as *Limited Method Availability (LMA)*. The second class covers outlets that primarily offer short acting methods, our *Short-Acting Methods (SAM)* class. The third class describes outlets stocking both short and long-acting methods, but not emergency contraception - we label this class as *All Non-EC Methods (ANEM)*.

Probability of assignment

Outlets had a greater probability of assignment to the *Short-Acting Methods* class (63.6%), exceeding the probability of assignment to the two other classes by three-to-one, with probability of assignment to the *Limited Method Availability* class statistically significantly higher than to the *All Non-EC Methods* class, (21.4% and 15.0%, respectively).

Postestimation Goodness-of-Fit

Average latent posterior probabilities for each class found a high degree of accuracy in predicting class membership for each outlet, with our on-diagonal measures of 0.895, 0.973, and 0.958 approaching or exceeding the generally accepted ideal threshold of 0.9 [20].

For the chosen three-class model, the Akaike's information criterion (AIC) and the Bayesian information criterion (BIC) were near the lowest value of the five models tested. For parsimonious reasons, the three-class model was chosen over the four- and five-class models where the AIC and BIC were marginally lower.

Entropy for the three-class model was calculated at 0.81, above the 0.80 acceptability threshold.

Latent class characteristics

Public and private sector outlets exhibit different probabilities of assignment to the three classes. Public sector outlets had a 60% probability of assignment to the *All Non-EC Methods* class, and around a 23% probability of assignment to the *Limited Method Availability* class. Private sector outlets meanwhile had a 75% probability of assignment to the *Short-Acting Methods* class. These differences were also reflected in outlet type, with smaller, private sector outlets (such as pharmacies and PPMVs) predominantly likely to be assigned to the S*hort-Acting Methods* class (93% and 85%, respectively). Hospitals and clinics were mostly likely to be assigned to the *All Non-EC Methods* class (57% and 60%, respectively), although were also quite likely to be assigned to the *Limited Method*

Availability class (38% and 27%, respectively). Primary health centers had the highest probability of assignment to the *All Non-EC Methods* class (80%).

Latent transition matrix

The trends in outlet latent class across the three rounds of data collection overall reveal an increasing probability of assignment to the *Short-Acting Methods* class (supplanting the *Limited Method Availability* class) over time (table 2; figure S3). Outlets in Nigeria's small urban site (Abia) exhibited the largest change in probability of assignment to the *Limited Method Availability* class (declining from 42% to 8% between rounds 1 and 3). The *Short-Acting Methods* class was the most prevalent overall, and at each site for every round, except for round 1 in the semi-urban site (Niger), which nevertheless saw the largest increase in probability of assignment to this class (from 38% in round 1 to 75% in round 3). Probability of assignment to the *All Non-EC Methods* class decreased slightly across rounds overall from 14% to 12% between rounds 1 and 3.

Overall, most outlets did not change class between rounds. Those in the *Limited Method Availability* were the most likely to transition to one of the other two classes between round 1 and 2 and round 2 and 3, although more than half of outlets remained in this class between each round (50% did not transition between rounds 1 and 2, and 57% did not transition between rounds 2 and 3) (table 2). Those in the *Short-Acting Methods* class were the most likely to remain in that class between rounds (91% and 97% persisting between rounds 1 and 2, and rounds 2 and 3, respectively). The likelihood of an outlet transitioning to a *Limited Method Availability* class was higher for those in the A*ll Non-EC Methods* class than in the *Short-Acting Methods* class (20% and 5% likelihood, respectively, between rounds 1 and 2). The patterns seen in outlets' class transition from rounds 1 to 2 closely matched that from round 2 to 3.

Characteristics of outlets in each class

Table S2 shows the characteristics of outlets in each class (or transitioning to other classes between rounds). Overall, 68% of all outlets are found to be remaining in the SAM class. This is due to the large proportion of pharmacies and PPMV/ drug shops in this class that do not transition. Public outlets are most likely to be found in, or transitioning to, the ANEM class. The most common class for both health facilities and hospitals is ANEM, although around a quarter of hospitals are remain in the LMA class. Figure 3 shows how outlets can be grouped into two broad types based on their class. Facilities (hospitals, health facilities and clinics) are predominantly within a mixture of ANEM and LMA classes (or transition to these classes), while pharmacies and PPMV/chemists are mostly in the SAM class, or transition to it. Pharmacies have the lowest proportion of outlets transitioning between classes across rounds (9 out of a total of 178 pharmacies), followed by PPMVs/chemists (85 out of 598). Hospitals had the highest rate of transition between classes (25 out of 84).

DISCUSSION

Research that has explored FP product availability and stockouts at the outlet level has tended to be cross-sectional in nature. While important in giving a snapshot of which products are available at a specific point in time or in aggregate over repeated cross-sectional assessments, prior work has failed to account for outlet-level change over time longitudinally, potentially masking shifts in product availability within outlets – the sites where consumers interface with the FP market. In this paper we use outlets as the unit of analysis and examine how product availability changes over time within outlets, we observe large levels of variability. This is particularly apparent for short-acting methods, and seen most commonly in smaller, private sector outlets. This contrasts with analyses of repeated cross-sectional data that have tended to present a relatively stable picture of FP supply at the level of a given study site (e.g., a large urban area).

Measures of outlet level variability in FP product availability or stockouts over time are complicated by the large number of different product types and by the fact that, within an outlet, products may be going in and out of stock at different times. Capturing that variability is important if we wish to begin to understand what may be driving it. Using latent class analysis, we identified three classes that characterize the product availability profiles of outlets in the study sites in Nigeria. These three classes allow us to summarize availability or stockout across products, and measure change over time for outlets that switch between classes. The three classes identified are as follows: *Limited Method Availability*, which is characterized by low availability across all product types within an outlet; *Short-Acting Methods*, which identifies outlets primarily stocking male condoms, OCP and EC (and some with injectables); and *All Non-EC Methods*, characterized by outlets with most or all (non-EC) methods in stock. These classifications are data-driven, meaning that they arose empirically through patterns in FP method availability seen in the data. However, we named them, based on reviewing the patterns of FP methods most commonly seen for outlets in each group. These classes/groupings offer a potential alternative way to characterize the FP supply side that may prove less arbitrary that indicators such "outlets with 3+/5+ methods available", as commonly relied on in FP monitoring and analysis, which are not designed to account for different method types. Latent classes allow us to capture underlying patterns in availability and stock out across six FP product types (including both long- and short-acting methods, and EC) simultaneously. We saw strong evidence that the three-class model is a good fit for the Nigeria CM4FP data. This methodological approach permits analysis of change over time by showing which outlets' FP product stocking patterns are changing between rounds, which shows up as a transition between classes.

Our results show that in the 9-month time frame covered by our analysis, some classes are more stable than others. Outlets in the *Short-Acting Methods* class have a very high probability of staying in that class between rounds. While those in the *Limited Method Availability* class have an approximately 45% chance of staying in that class between rounds (meaning that over half were predicted to transition out of this class, going from limited method availability to another categorization). When exploring which outlets are most likely to be associated with each class, and to move between classes, it is interesting to note that pharmacies and PPMV/chemists appear the least likely to transition from one class to another. Both outlet types are likely to have short acting methods available over the 9-

month period covered by these data. Hospitals are the most likely to move between different classes in our analysis, and in particular between *Limited Method Availability* and *All Non-EC Methods* classes (in either direction). This is perhaps counterintuitive, but we hypothesize it may be due to higher FP client flows in hospitals that result in a more dynamic FP stocking picture. We note that the majority of hospitals in the dataset were in the private sector. Different levels of dynamism between outlet types may also be linked to different suppliers and supply chain challenges. Indeed, reported cuts to national family planning budgets in Nigeria in 2019 [21] may have impacted FP supply chains during the study. While beyond the scope of this paper, we suggest that issues with stock forecasting could be improved with a better understanding of product stock dynamics. Overall, the results suggest that while pharmacies and PPMVs stock fewer methods in the study sites in Nigeria, they can be considered a fairly consistent source of those methods. Outlet types stocking the more complete range of FP methods, usually larger facilities, appear to have less reliable product stocking. This has important implications for expanding FP in pharmacies and PPMVs which are often characterized as unreliable product sources, but that our results suggest to be quite stable. Our results support a recent work in Nigeria demonstrating the potential for task-shifting injectables provision to PPMVs.[16,22]

The descriptive findings that availability of individual methods at the outlet level changes much more commonly that the aggregate data would suggest, alongside findings from the latent class analysis that indicate some outlets are predicted to change class quite commonly represent a potential argument for analysis of FP markets that aggregate product availability patterns within outlets, rather than aggregating outlets across geographies. This alternative approach enables an alternative perspective on FP product dynamism, which in turn would allow the analysis of drivers of that change over time, and what effect outlet-level stock dynamism has on consumer behavior and FP access, uptake and continuation. Further research might consider exploring the extent to which outlet-level supply side dynamism measurably impacts the demand side of the market, and further, what effect dynamism in individual FP product brands might have on consumer behavior.

Limitations

The longitudinal outlet data used in this analysis allows us to track within-outlet change in FP product availability over time. However, the 9-month time frame for the CM4FP data collection in Nigeria means we were unable to account for any potential seasonal variation in contraceptive stocking or availability. Our analysis focused on only the six most common product types and did not account for different product brands. Future analyses could further disaggregate to brand level in the CM4FP data. Product availability is only one component of FP access [23,24] and future analysis could use the CM4FP dataset to investigate price variability and geographic access measures.

Employing a data-driven approach such as LCA to the CM4FP Nigeria data means that the generalizability of the results may be limited. We have conducted preliminary sensitivity analysis using the CM4FP Kenya outlet data.

CONCLUSION

This paper has demonstrated the potential utility of using outlet-level longitudinal data to explore how the total market for FP in study areas changes over time. Outlet level analysis suggests that even when aggregate measures of availability are relatively stable, the supply side of FP markets can be dynamic – products going in and out of stock – within a relatively short time. This has important implications for future research focusing on product availability and stockout prevalence and on the demand side experience of access to FP. Using FP outlet panel data from Nigeria, the application of latent class analysis allows for the development of three "classes" that were used to characterize the FP product availability profiles of the outlets, and then to explore how they change over time. Larger facilities, supplying a fuller range of FP products had the highest chance of changing between classes, and thus were the most dynamic in their FP product availability or stocking status, while smaller private sector outlets such as pharmacies and PPMVs were most stable, although tended to offer a more limited range of FP products. The latent class approach for characterizing and comparing outlets represents an alternative data-grounded technique, to the current use of 3+ and 5+ methods indicators common in the literature. Comparing outlets through this approach arguably allows practitioners and researchers to understand the nuances of FP supply side dynamics through an alternative lens, and to develop programming and research where differences in outlets are captured by more than arbitrary thresholds of the number of methods available.

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COMPETING INTERESTS

None declared.

DATA AVAILABILITY

All data and documentation for the CM4FP project are available on the project website (www.cm4fp.org).

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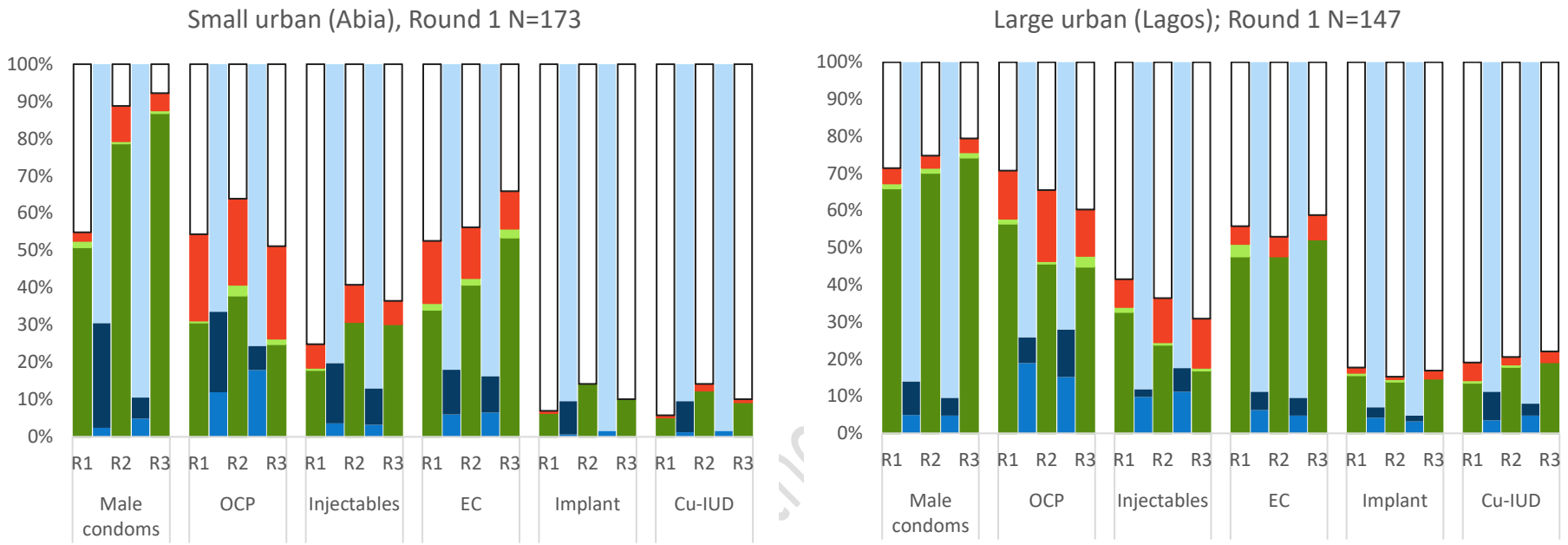
TABLES AND FIGURES

Figure 1 Stock Dynamism in Nigeria



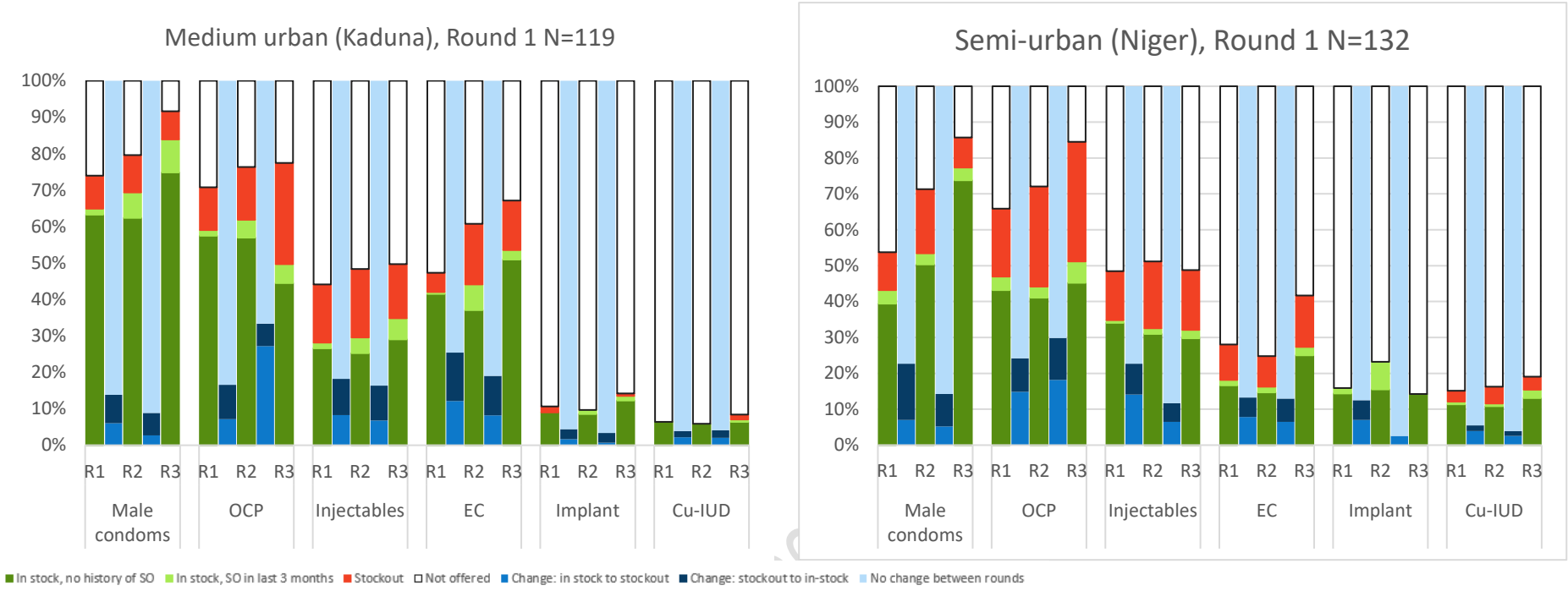


Figure 2 Latent Classes

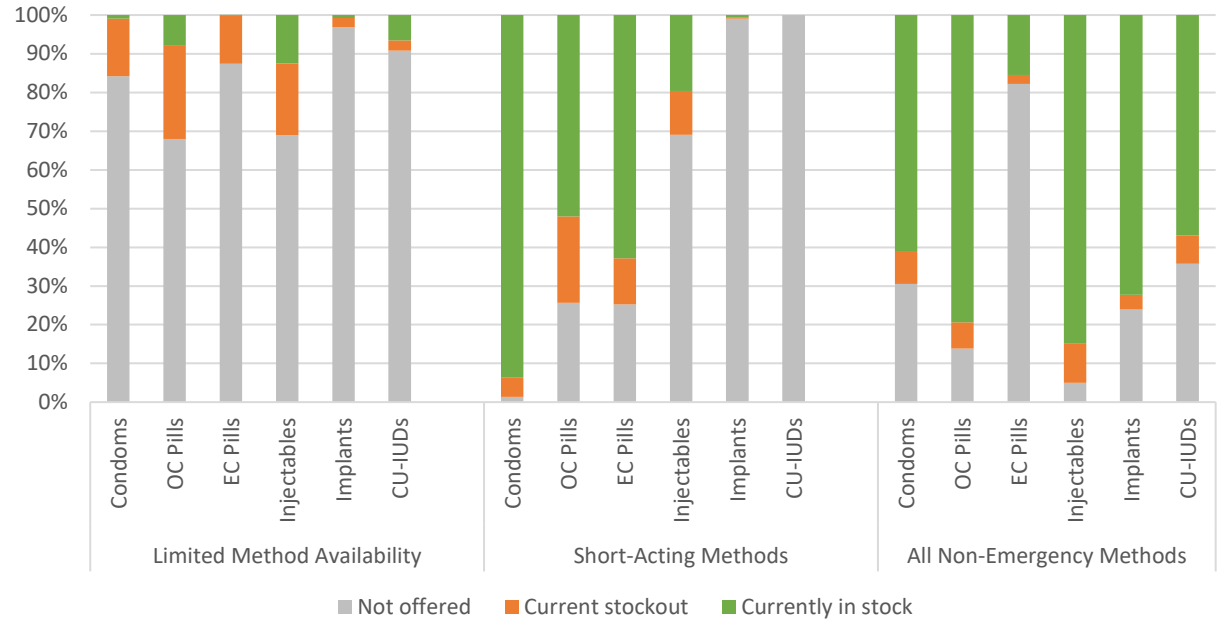


Figure 3: Relative Distributions of Classes by Outlet Type

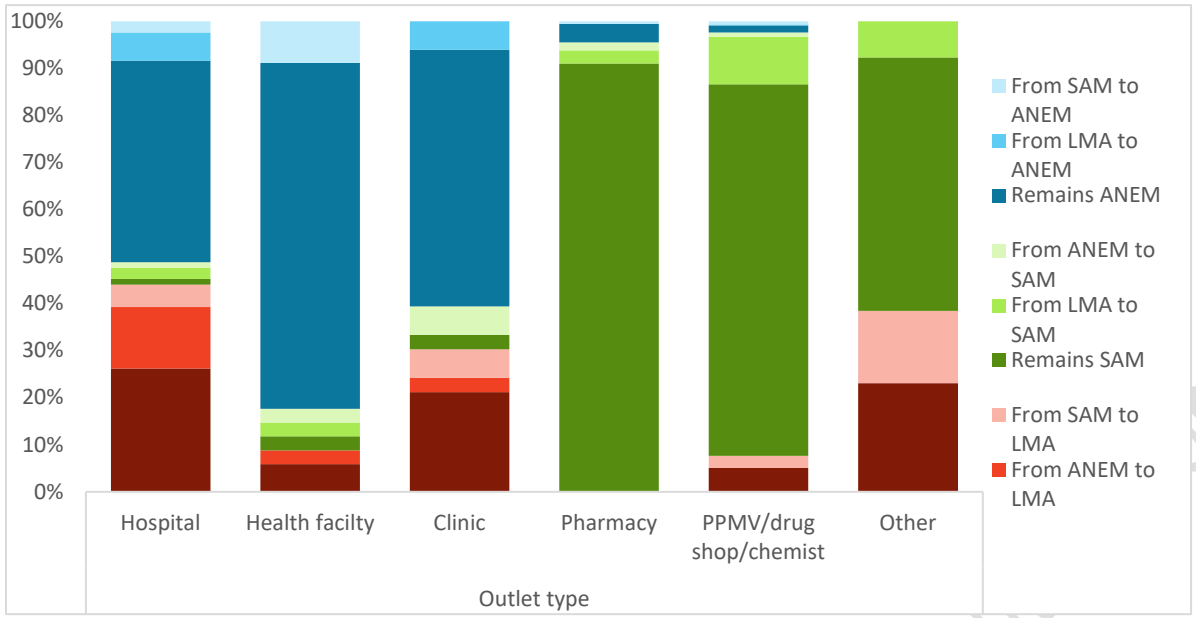


Table 1 Probability of Assignment to Latent Classes by Site, Outlet Characteristics, and Round

Latent class by site	Round 1	Round 2	Round 3
Large urban (Lagos site)			
Limited Method Availability	21 (15.1%)	26 (18.3%)	14 (11.8%)
Short-Acting Methods	88 (63.3%)	91 (64.1%)	92 (77.3%)
All Non-EC Methods	30 (21.6%)	25 (17.6%)	13 (10.9%)
Medium urban (Kaduna site)			
Limited Method Availability	26 (16.3%)	17 (10.8%)	15 (10.5%)
Short-Acting Methods	113 (70.6%)	124 (78.5%)	117 (81.8%)
All Non-EC Methods	21 (13.1%)	17 (10.8%)	11 (7.7%)
Small urban (Abia site)			

Limited Method Availability	37 (28.5%)	6 (4.7%)	11 (8.5%)
Short-Acting Methods	82 (63.1%)	105 (82.0%)	104 (80.0%)
All Non-EC Methods	11 (8.5%)	17 (13.3%)	15 (11.5%)
Semi-urban (Niger site)			
Limited Method Availability	24 (29.3%)	10 (12.5%)	8 (11.3%)
Short-Acting Methods	42 (51.2%)	52 (65.0%)	56 (78.9%)
All Non-EC Methods	16 (19.5%)	18 (22.5%)	7 (9.9%)
Overall			
Limited Method Availability	108 (21.1%)	59 (11.6%)	48 (10.4%)
Short-Acting Methods	325 (63.6%)	372 (73.2%)	369 (79.7%)
All Non-EC Methods	78 (15.3%)	77 (15.2%)	46 (9.9%)

	Limited Method Availability	**Short-Acting Methods**	**All Non-EC Methods**
Managing Authority			
Government/public	9 (11.5%)	9 (11.5%)	60 (76.9%)
Private	206 (14.7%)	1057 (75.3%)	141 (10.0%)
Outlet Type			
Hospital	57 (38.5%)	10 (6.8%)	81 (54.7%)
Primary health center	5 (8.5%)	7 (11.9%)	47 (79.7%)
Clinic	15 (31.3%)	6 (12.5%)	27 (56.3%)
Maternity Clinic	5 (29.4%)	2 (11.8%)	10 (58.8%)
Pharmacy	5 (1.8%)	253 (93.0%)	14 (5.1%)
PPMV/drug shop/chemist	124 (13.5%)	773 (84.1%)	22 (2.4%)
Other	6 (28.6%)	15 (71.4%)	

Table 2 Latent Transition Matrix

	Round 2				Round 3		
	LMA	SAM	ANEM		LMA	SAM	ANEM

	LMA	**0.36**	0.59	0.05		LMA	**0.67**	0.26	0.07
Round 1	SAM	0.04	**0.93**	0.03	Round 2	SAM	0.03	**0.97**	0.01
	ANEM	0.04	0.04	**0.93**		ANEM	0.13	0.10	**0.77**

LMA: Limited Method Availability; SAM: Short-Acting Methods; ANEM: All Non-EC Methods
Values represent the proportion of outlets in each class conditional on their class in the previous round

Supplemental tables and figures

Table S1 Stock Dynamism in Nigeria

			Abia					Kaduna					Lagos					Niger				
			R1	Change	R2	Change	R3	R1	Change	R2	Change	R3	R1	Change	R2	Change	R3	R1	Change	R2	Change	R3
	N		**173**	**167**	**169**	**123**	**129**	**188**	**181**	**186**	**147**	**155**	**147**	**143**	**151**	**125**	**136**	**132**	**128**	**129**	**77**	**84**
Male condoms	Available	n	91	**51**	134	**13**	113	122	**25**	129	**13**	130	99	**20**	108	**12**	103	57	**29**	69	**11**	65
		%	70%	**24%**	77%	**13%**	81%	84%	**9%**	83%	**10%**	88%	81%	**11%**	77%	**19%**	66%	69%	**20%**	80%	**12%**	77%
	Not available	n	82		35		16	66		57		25	48		43		33	75		60		19
		%	30%		23%		19%	16%		17%		12%	19%		23%		34%	31%		20%		23%
OCP	Available	n	54	**56**	69	**30**	34	111	**30**	115	**49**	77	85	**37**	70	**35**	65	62	**31**	57	**23**	43
		%	77%	**24%**	76%	**20%**	76%	86%	**16%**	84%	**18%**	84%	85%	**13%**	86%	**11%**	84%	55%	**22%**	56%	**21%**	54%
	Not available	n	119		100		95	77		71		78	62		81		71	70		72		41
		%	23%		24%		24%	14%		16%		16%	15%		14%		16%	45%		44%		46%
Injectables	Available	n	32	**33**	52	**16**	39	53	**33**	55	**24**	54	50	**17**	37	**22**	24	46	**29**	42	**9**	27
		%	22%	**11%**	29%	**20%**	44%	43%	**14%**	43%	**16%**	49%	26%	**34%**	46%	**15%**	53%	39%	**28%**	44%	**39%**	30%
	Not available	n	141		117		90	135		131		101	97		114		112	86		87		57
		%	78%		71%		56%	57%		57%		51%	74%		54%		47%	61%		56%		70%
EC	Available	n	62	**30**	72	**20**	72	79	**46**	82	**28**	83	75	**16**	72	**12**	71	24	**17**	21	**10**	23
		%	55%	**20%**	57%	**21%**	68%	68%	**19%**	68%	**13%**	69%	76%	**18%**	72%	**17%**	70%	47%	**23%**	47%	**18%**	46%
	Not available	n	111		97		57	109		104		72	72		79		65	108		108		61
		%	45%		43%		32%	32%		32%		31%	24%		28%		30%	53%		53%		54%
Implants	Available	n	11	**16**	24	**2**	13	17	**8**	18	**5**	21	24	**10**	22	**6**	20	21	**16**	30	**2**	12
		%	13%	**4%**	15%	**5%**	19%	28%	**6%**	28%	**5%**	28%	32%	**9%**	40%	**3%**	39%	28%	**2%**	33%	**9%**	44%
	Not available	n	162		145		116	171		168		134	123		129		116	111		99		72
		%	87%		85%		81%	72%		72%		72%	68%		60%		61%	72%		67%		56%
Cu-IUD	Available	n	9	**16**	21	**2**	12	12	**7**	11	**6**	11	21	**16**	28	**10**	26	16	**7**	15	**3**	13
		%	13%	**6%**	12%	**7%**	16%	15%	**5%**	17%	**7%**	19%	22%	**5%**	28%	**4%**	29%	25%	**5%**	25%	**5%**	28%
	Not available	n	164		148		117	176		175		144	126		123		110	116		114		71
		%	87%		88%		84%	85%		83%		81%	78%		72%		71%	75%		75%		72%

Table S2 Characteristics of outlets by change in class

		Remains LMA	From LMA to SAM	From LMA to ANEM	Remains SAM	From SAM to LMA	From SAM to ANEM	Remains ANEM	From ANEM to LMA	From ANEM to SAM	**Total**
Outlet type	Hospital	22 (26%)	2 (2%)	5 (6%)	1 (1%)	4 (5%)	2 (2%)	36 (43%)	11 (13%)	1 (1%)	**84 (100%)**
	Health facility	2 (6%)	1 (3%)	0 (%)	1 (3%)	0 (%)	3 (9%)	25 (74%)	1 (3%)	1 (3%)	**34 (100%)**
	Clinic	7 (21%)	0 (%)	2 (6%)	1 (3%)	2 (6%)	0 (%)	18 (55%)	1 (3%)	2 (6%)	**33 (100%)**
	Pharmacy	0 (%)	5 (3%)	0 (%)	162 (91%)	0 (%)	1 (1%)	7 (4%)	0 (%)	3 (2%)	**178 (100%)**
	PPMV/ drug shop	30 (5%)	60 (10%)	1 (%)	465 (79%)	15 (3%)	4 (1%)	9 (2%)	0 (%)	5 (1%)	**589 (100%)**
	Other	3 (23%)	1 (8%)	0 (%)	7 (54%)	2 (15%)	0 (%)	0 (%)	0 (%)	0 (%)	**13 (100%)**
	Total	**64 (7%)**	**69 (7%)**	**8 (1%)**	**637 (68%)**	**23 (2%)**	**10 (1%)**	**95 (10%)**	**13 (1%)**	**12 (1%)**	**931 (100%)**
Managing authority	Gov't/public	3 (7%)	1 (2%)	1 (2%)	1 (2%)	1 (2%)	3 (7%)	29 (67%)	2 (5%)	2 (5%)	**43 (100%)**
	Private	61 (7%)	68 (8%)	7 (1%)	636 (72%)	22 (2%)	7 (1%)	66 (7%)	11 (1%)	10 (1%)	**888 (100%)**
	Total	**64 (7%)**	**69 (7%)**	**8 (1%)**	**637 (68%)**	**23 (2%)**	**10 (1%)**	**95 (10%)**	**13 (1%)**	**12 (1%)**	**931 (100%)**
Source of FP	Wholesale pharmacy	26 (6%)	44 (10%)	2 (%)	354 (77%)	13 (3%)	3 (1%)	11 (2%)	5 (1%)	0 (%)	**458 (100%)**
	Retail pharmacy	4 (8%)	3 (6%)	0 (%)	39 (74%)	3 (6%)	0 (%)	2 (4%)	1 (2%)	1 (2%)	**53 (100%)**
	Gov't medical stores	2 (6%)	1 (3%)	1 (3%)	0 (%)	0 (%)	3 (9%)	25 (74%)	1 (3%)	1 (3%)	**34 (100%)**
	Health facility	1 (7%)	1 (7%)	0 (%)	3 (21%)	2 (14%)	0 (%)	6 (43%)	1 (7%)	0 (%)	**14 (100%)**
	NGO	1 (2%)	4 (9%)	3 (6%)	15 (32%)	0 (%)	2 (4%)	17 (36%)	3 (6%)	2 (4%)	**47 (100%)**
	Sales rep./ distributor	13 (5%)	13 (5%)	2 (1%)	167 (69%)	4 (2%)	1 (%)	33 (14%)	2 (1%)	6 (2%)	**241 (100%)**
	Other	2 (3%)	3 (5%)	0 (%)	56 (85%)	1 (2%)	1 (2%)	1 (2%)	0 (%)	2 (3%)	**66 (100%)**
	Total	**49 (5%)**	**69 (8%)**	**8 (1%)**	**634 (69%)**	**23 (3%)**	**10 (1%)**	**95 (10%)**	**13 (1%)**	**12 (1%)**	**913 (100%)**

Figure S1. Latent Class Transitions