



## NON- PARAMETRIC MULTIPLE INPUTS PREDICTION MODEL FOR QUANTITY OF INFANT-FORMULA DEMANDED FOR CHILDREN AGED 0 – 24 MONTHS IN ILORIN-SOUTH, NIGERIA

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### ABSTRACT

Infant-formula is recommended by the World Health Organisation as the safest form of complementary food to human breast milk. Breastfeeding duration and other imperative input-factors that govern quantity of infant-formula demanded (a modulus variable) is difficult to model and predict with high precision. However, infants based on their conventional rights have to be given good nutrition. This study is necessitated by the challenging process of complex modulus prediction of quantity of infant-formula demanded to complement human breast milk, which may be attributed to differences in maternal characteristics at various maternal geographical settlement areas. Owing to complex nature of the differences, we propose a data-driven approach for handling larger-scale scenarios which may be limited in the conventional parametric modelling methods. This study aims at investigating the association of maternal characteristics with quantity of infant -formula demanded among breastfeeding mothers who have children aged 0 – 24 months in Ilorin-South Local Government Area, Nigeria. Primary data were collected from 744 breastfeeding mothers. We adopted appropriate non-parametric tests to determine the impact of different independent groups of maternal covariate factors considered on quantity of infant -formula demanded. Multi-associations were assessed and negative binomial model was formulated to predict estimated quantity of infant-formula demanded for various breastfeeding durations. The results show that increase in breastfeeding duration leads to increase in quantity of infant-formula demanded. In future intervention studies, factors that have significant effect on demand for infant-formula might be considered for proper monitoring of infant feeding.

**Keywords:** Breastfeeding, infant-formula, non-parametric tests, negative binomial model

### INTRODUCTION

In the field of child nutrition, after age 6 months of a child, it is paramount to introduce safe complementary foods that have adequate nutrition for child consumption. This must be combined with breastfeeding up to age 2 years to ensure meeting the nutrient and energy needs of infants as they advance in age (Ogbo et al., 2008; Agbo et al., 2019; and Abdullahi et al., 2022). The modern and improved nutrition in children aged 0-24months should be such that children are fed with breast milk and mothers may later combine with infant-formula feeding, which is the safest complementary food, particularly after 6 months of exclusive breastfeeding (Zakarija- Grković et al., 2020 and Huang et al., 2016). According to Liu et al., (2022); Azad et al., (2018); Austin et al., (2019); Samuel et al., (2019) and Ogbonna et al., (2022), it was argued that human milk oligosaccharides (HMOs) concentration may be related to certain characteristics of breastfeeding mothers. Impact of maternal characteristics of breastfeeding mothers may not be the same on Human milk oligosaccharides among women in different geographical areas (McGuire et al., 2017). Iron-fortified infant-formula should be made available for consumption of infants that are weaned before 1 year of age and not cow milk feedings (Sharfstein and Silver, 2017). There are many scientific information on breast and formula feeding for educative decision on child nutrition (Liu et al. 2019; Sharfstein and Silver 2017).

The appropriate food for infant nutrition is breast milk, but based on different possibilities, breastfeeding may be terminated at varying durations in the life of an infant. Sometimes, when this happen, formula feeding is used as an

alternative (Rossen et al., 2016). Variations in breastfeeding durations and demand of infant-formula may be broadly based on different mothers' individual characteristics and settlement areas; or the individual characteristics of the children (Ogbo et al., 2008). Many mothers terminate breastfeeding after 18 months, this may contribute to poor child's nutrition or the risks of prolonged breastfeeding (Syeda et al., 2021 and Oladoyinbo et al., 2016). To reduce the burden of under-nutrition and prolonged breastfeeding, our present study is an extension of their work, whereby we investigate the impact of breastfeeding duration on demand of infant-formula (Infant formula being considered as a safe alternative to ease the burden of prolonged breastfeeding). Also, this study examines whether quantity demanded of infant-formula is equally distributed across other considered imperative maternal characteristics factors.

Furthermore, in some aspects of infant health nutrition, non-parametric tests have been applied to studies on postnatal nutrition. In the early-lives of infants, it is important to follow-up their nutrition after birth to ensure proper growth and avoid long-term implications of ill health (Lanigan and Singhal, 2009). Consequently, the effect of maternal health behaviours and social conditions on childhood nutrition as assessed in the region of Ontario, Canada is critical to provide strategies to elevate health during childhood (Wahi et al., 2013 and Wahi et al., 2022).

Specifically, this present study aims to investigate whether quantity demanded of infant-formulae is equally distributed across considered maternal factors of breastfeeding mothers in the study geographical settlement of Ilorin-South Local Government Area (L.G.A), Kwara State, Nigeria for:

breastfeeding mothers who practise either of the two major religions (Christianity and Islam); literacy level; family structure; mothers' age; mothers' marital status; breastfeeding duration; tribe; and child age. Also, the study identifies the direction of linear relationship that exists among some of the maternal characteristics in the study area. Broadly, this study introduces a platform to predict quantity demanded of infant-formula as a function of different possible maternal characteristics among breastfeeding mothers who have children aged 0 – 24 months in Ilorin-South Local Government Area, Nigeria. Owing to complex nature of the differences and to limit regional conflicting results on the subject around the globe, we propose a data-driven approach for predicting quantity of infant-formula demanded using the negative binomial model.

## MATERIALS AND METHODS

### Study design and location

This work is descriptive and longitudinal in design. It was conducted in Ilorin-South Local Government Area, Kwara State, Nigeria to collect primary data on maternal characteristics, social conditions and quantity demanded of infant-formula for childhood nutrition among breastfeeding mothers who have children aged 0 – 24 months.

### Sample selection

A multi-stage sampling technique was employed in selecting 1103 communities from the 11 wards in Ilorin-South L.G.A, Kwara State, Nigeria. From the list of households in the communities, 744 households were selected using purposive sampling to recruit breastfeeding mothers and their infant pairs that are aged two years and below for our study.

### Data collection

A population-based longitudinal study was conducted in the year 2018-2020 prior the year of our survey and 744 breastfeeding mothers were purposefully selected to collect data on them and their infant pairs that are aged 0-24 months. A structured questionnaire was used to collect information from breastfeeding mothers on: child variables; breastfeeding mothers' bio-data and their socio-demographic characteristics; and their monthly estimated quantity of demand for infant-formula. The 744 households of the breastfeeding mothers were examined for impact of different maternal characteristics on demand of infant-formula at the end of the two years. The information on choice of predictor variables was informed from literature on socio-demographic factors that have association with maternal characteristics of breastfeeding mothers. Other relevant materials on wards and communities in Ilorin-south were obtained from the most current reports of National Population Commission (nationalpopulation.gov.ng) as at the time of our study.

### Data analysis for quantity of infant-formula demanded

There are various parametric and non-parametric statistical tests that have been applied in different fields of study. For example, Qualls et al., (2019) showed some of the applications in medicine. We used the non-parametric tests of Wilcoxon rank-sum test to determine the impact of two independent groups of the different maternal covariate factors considered on quantity of infant-formula demanded. The Wilcoxon rank sum test with continuity correction is being implemented to investigate whether infant-formula quantity demanded is the same for two major religions as well as literacy level among breastfeeding

mothers in the study area. The test statistic is calculated by joining two samples and ranking all observations in ascending order while noting the sample which each observation belongs (Makinde et al., 2021). The Wilcoxon rank-sum test rejects null hypothesis that two groups are identically distributed with respect to their infant -formula quantity demanded if the p-value of the test is less than the value of significance level.

The Kruskal-Wallis test also known as H test (Kruskal & Wallis, 1952) is a non-parametric test based on ranks of observations and an advancement of the Wilcoxon rank sum test. It is used to compare three or more independent groups on a continuous scale so as to examine if there are statistically significant differences among them. For example, Saharuddin et al., (2022) used the non-parametric statistical test to forecast a dependent variable based on various input factors. In our present study, the Kruskal-Wallis test is being used to examine three or more independent groups of the different maternal covariate factors considered on quantity of infant-formula demanded. Dunn's test is being used for pairwise comparisons between maternal characteristics and quantity of infant-formula demanded to determine which groups are exactly different in the statistically significant results of Wilcoxon rank-sum test and Kruskal-Wallis test. Multi-association analyses between breastfeeding duration and maternal characteristics; and impact of maternal characteristics on quantity of infant-formula demanded were assessed using Spearman rank correlation test. Negative binomial regression model was formulated to predict estimated quantity of infant-formula demanded for various breastfeeding durations. The results reveal that different input factors have various output for quantity of infant-formula demanded

In this work, negative binomial (NB) regression model was formulated to predict quantity of infant-formula demanded for different breastfeeding durations. The negative binomial regression is:

$$f(y|x) = \frac{\Gamma(y + \theta)}{y! \Gamma(\theta)} \left( \frac{\theta}{\theta + \mu} \right)^\theta \left( \frac{\mu}{\theta + \mu} \right)^y, \quad (1)$$

where  $\log_e(\mu) = x'\beta$ ,  $y$  represents the estimated quantity of infant-formula demanded,  $x$  represents the breastfeeding durations. The negative binomial regression model is formulated as:

$$E(y|x) = e^{x'\beta}, \quad (2)$$

where  $\mu$  is the conditional mean,  $\beta = \begin{pmatrix} \beta_0 \\ \beta_1 \end{pmatrix}$  is the vector of model coefficients. This can be expressed as:

$$\mu = \exp(\beta_0 + \beta_1 x), \quad (3)$$

where  $x$  represents breastfeeding duration,  $\mu = E(y|x)$  is the conditional expectation of estimated quantity of infant-formula demanded. The maximum likelihood estimator is being used to estimate the parameters of the model.

## RESULTS AND DISCUSSION

For multi-association among the maternal characteristics, we adopted the Spearman rank correlation test. The findings reveal that family structure is positively correlated with husbands' qualification and occupation at ( $r=0.4012$ ,  $p\text{-value}=0.00$ ) and ( $r=0.4143$ ,  $p\text{-value}=0.00$ ) respectively. Similarly, marital status was found strongly positively correlated with husband's qualification and occupation at ( $r=0.8745$ ,  $p\text{-value}=0.00$ ) and ( $r=0.8612$ ,  $p\text{-value}=0.00$ ) respectively. The test of significance

of the correlation values show that the correlation values are significantly different from zero as the associated p-values are less than 1% level of significance.

Spearman rank correlation analysis shows that for the maternal characteristics considered in our study area, breastfeeding

duration is not significantly correlated with: either of the two major religions (Christianity and Islam) practised by breastfeeding mothers in the L.G.A; tribe, parity, maternal age, occupation, awareness on breastfeeding, maternal settlement area; and child gender.

**Table 1: Correlation estimates and p-values for significance test between breastfeeding duration and significant variables obtained from the results at 5% level of significance**

	Family Structure	Estimated Quantity Demanded	Child age	Literacy	Qualification	Husband's Occupation	Husband's Qualification
correlation value	-0.137	0.470	0.488	-0.083	0.079	-0.264	-0.169
p-value	0.000	0.000	0.000	0.024	0.032	0.000	0.000

Table 1 presents the estimates of correlation coefficients and p-values for significance test between breastfeeding duration and significant variables obtained from the results at 5% level of

significance. It was found that breastfeeding duration is negatively linearly related with family structure, maternal literacy, husbands' occupation and qualification.

**Table 2: Correlation estimates and p-values for significance test between estimated quantity of infant-formula demanded and significant variables obtained from the results at 5% level of significance**

	Breastfeeding Duration	Child age	Maternal age	Literacy	Qualification	Husband Qualification
correlation value	0.470	0.940	-0.173	-0.309	0.194	0.127
p-value	0.000	0.000	0.000	0.000	0.000	0.001

Table 2 presents the estimates of correlation coefficients and p-values for significance test between estimated quantity of infant-formula demanded and significant variables obtained from the results at 5% level of significance. Child age and breastfeeding duration are positively strongly correlated with estimated quantity of infant-formula demanded.

Figure 1 presents the correlogram of variables of interest. Linear relationship among the variables is presented in terms of their magnitude and direction. According to the findings of the study, negative correlation between maternal literacy and breastfeeding period implies that the higher the level of literacy of a breastfeeding mother, the less the breastfeeding period, which may lead to increase in quantity of infant-formula demanded as a form of complementary and alternative food for

infants. Also, a child well breastfed may likely have a higher appetite for food after a prolonged breastfeeding period. Many factors may contribute to adequate breastfeeding duration, which include attending maternal education, having two to three children before the birth of another child (parity), previous breastfeeding experience, support from husbands or partners of breastfeeding mothers, and health conditions during pregnancy (Ballesta-Castillejos et al., 2020). Recent studies considered the association between exclusive breastfeeding and mothers' literacy. For example, Laksono et al., (2021) showed that mother's qualification is positively related to exclusive breastfeeding possibility in children less than 6 months old in Indonesia.

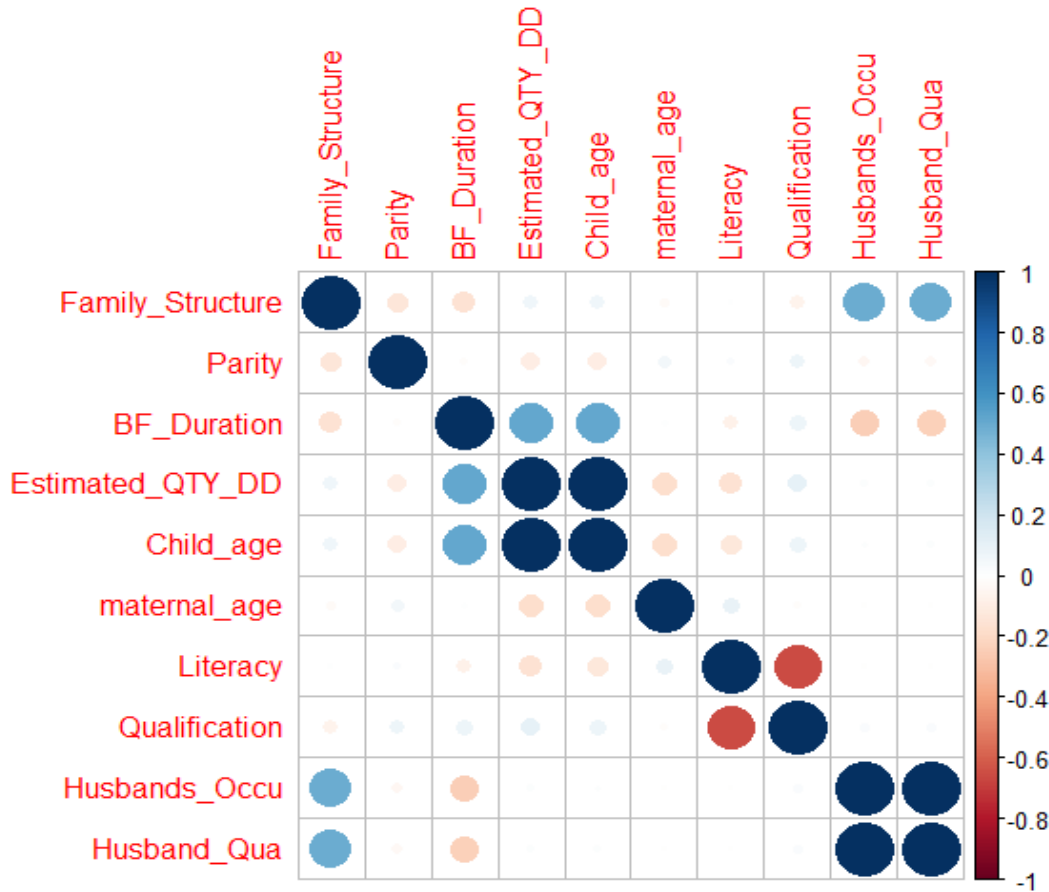


Figure 1: Correlogram of Spearman rank correlation among variables of interest.

Kruskal-Wallis test was adopted to examine if estimated infant-formula quantity demanded in the study L.G.A are equally distributed among breastfeeding mothers across tribes, family structures, parity, maternal age groups, occupation types, literacy levels, qualification types; and child age groups. The result shows that distribution of estimated infant-formula quantity demanded is not the same across tribes in the study L.G.A ( $p$ -value = 0.009), as well as child age groups ( $p$ -value = 0.000), maternal age groups ( $p$ -value = 0.000), occupation types ( $p$ -value = 0.000) and qualification types ( $p$ -value = 0.000). Also, the results show that the estimated infant-formula quantity demanded is equivalently distributed among different family structures ( $p$ -value = 0.206) and parity ( $p$ -value = 0.096). Dunn test (Dunn, 1964) of multiple comparisons following a significant Kruskal-Wallis test shows that there is no significant difference in estimated infant-formula quantity demanded by breastfeeding mothers who have no formal education and those with only primary education. A similar result was obtained for breastfeeding mothers with secondary education and those with tertiary education. A significant difference in estimated quantity demanded of infant-formula is observed between breastfeeding mothers with no formal education and those with secondary education ( $p$ -value 0.0004). A similar result was obtained

between breastfeeding mothers with primary education and those with secondary education ( $p$ -value 0.0000); as well as those with no formal education and those with tertiary education ( $p$ -value 0.0026); those with primary education and those with tertiary education ( $p$ -value 0.0000). All the age groups of children are significantly different from one another at 1% level of significance. This is shown in Figure 2. The Dunn test also reveals that mother's age has direct implication on the quantity of infant-formula demanded based on all the age groups of mothers (16-25 years, 26-35 years, 36-45 years) that are significantly different from one another at 1% level of significance.

Wilcoxon rank-sum test (Mann & Whitney, 1947) was applied to examine if either religion (Christianity and Islam) or literacy level of the breastfeeding mothers affect the distribution of infant-formula quantity demanded. The results show that the estimated infant-formula quantity demanded is equally distributed between the two religions ( $p$ -value=0.9439). However, literacy levels of the breastfeeding mothers may significantly affect quantity of infant-formula demanded ( $p$ -value = 0.000). The result shows that average quantity demanded of infant-formula is higher among literate breastfeeding mothers than illiterate breastfeeding mothers.

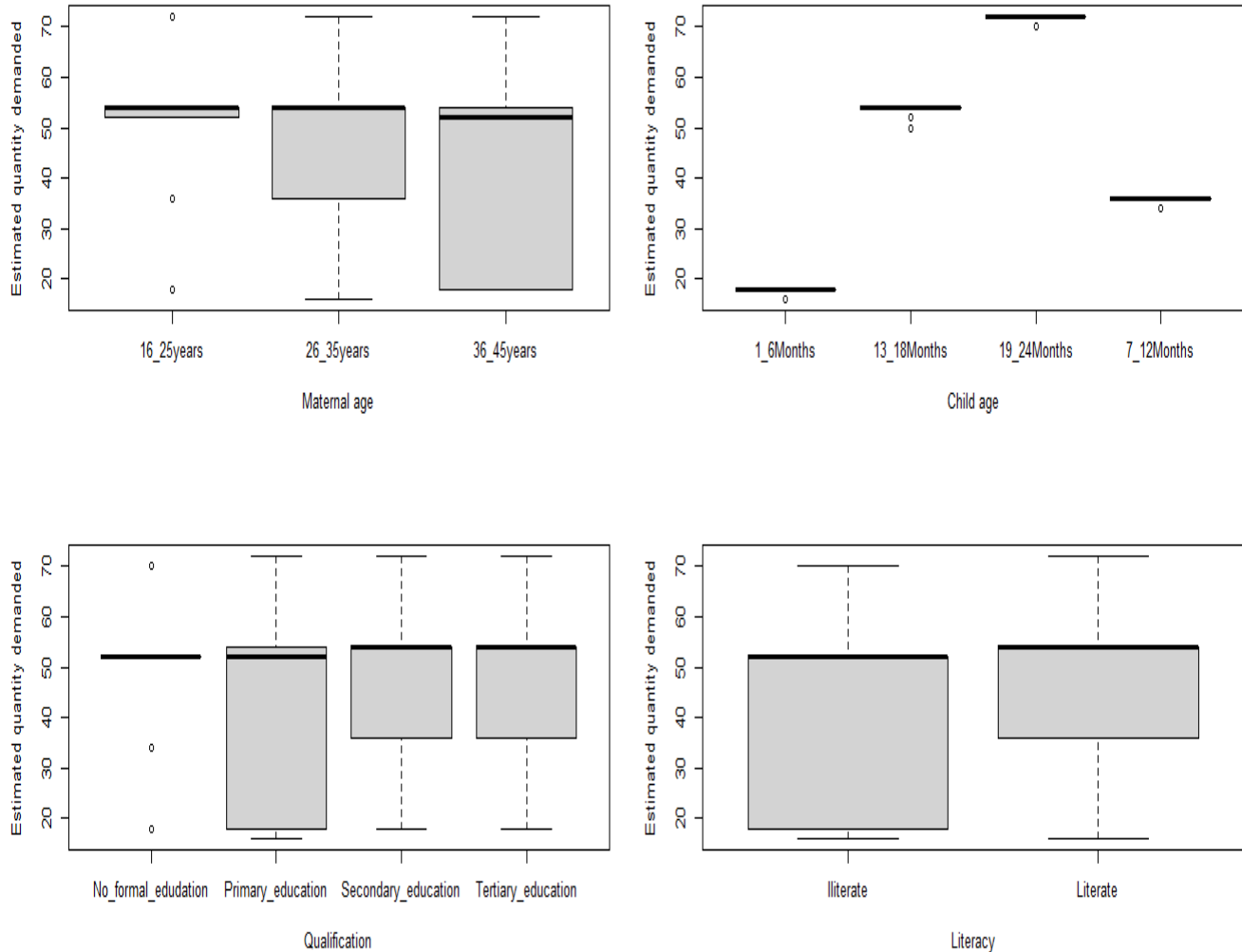


Figure 2: Boxplot of estimated infant-formula quantity demanded by maternal age, child age, qualification and literacy level

**Table 3: Estimates of coefficients of the fitted Negative Binomial regression model**

Predictors	Estimate	Std.Error	z-value	Pr(> z )
Intercept	3.5096	0.0263	133.2	<2e-16***
Breastfeeding Duration	0.0324	0.0022	14.55	<2e-16***

Signif. codes: ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05

Dispersion parameter for Negative Binomial(12.2901) family taken to be 1

Null deviance: 992.04 on 743 degrees of freedom

Residual deviance: 787.00 on 742 degrees of freedom

AIC: 6136.5

Theta: 12.290, Std. Err.: 0.842

A negative binomial regression model is formulated to predict the estimated infant-formula quantity demanded being dictated by breastfeeding duration. This model was fitted for predictive and inferential purposes. The results show that estimates of the coefficients of the breastfeeding duration were statistically significant at 5% level of significance.

Table 3 presents the estimates of coefficients of negative binomial regression model for infant-formula quantity demanded. The infant-formula quantity demanded increases by

a factor of 1.0774 for one-unit increase in breastfeeding duration. This implies there is positive association between breastfeeding duration and estimated quantity of infant-formula. That is, as breastfeeding duration increases, estimated quantity of infant-formula increases. This is in agreement with the correlogram in Figure 1.

Mathematically, the estimated negative binomial regression model can be written as:

$$\mu = \exp(3.5096 + 0.0324 \times \text{breastfeeding duration}). \quad (4)$$

It is necessary to investigate whether the fitted negative binomial model fits the data statistically better than null model. The Vuong test is employed to do this. The result suggests that negative binomial model fits the data better than the null model ( $p\text{-value} = 0.000$ ). The pseudo- $R^2$  for the fitted model is 0.2067, indicating the model fits the data excellently.

Recent study has shown that longer duration of exclusive and partial breastfeedings tend to be related with slower growth rates during infancy in the developed country setting only. The associations appeared to be dose dependent and more pronounced in exclusively versus partially breastfed infants. Also, recent study has shown that infants who were exclusively breastfed for half a year do experience less morbidity from gastrointestinal infection than those who are partially breastfed for three to four months. The study also claimed that there were no deficits in growth among infants from either developing countries such as Nigeria or developed countries who are exclusively breastfed for six months or longer (Kramer & Kakuma, 2012).

## CONCLUSION

This present study provides answer to the question that arises from whether quantity demanded of infant-formula is equally distributed across considered imperative maternal characteristics factors as well as deriving association between estimated quantity of infant-formula demanded and breastfeeding duration. In this study, estimated quantities of infant-formula demanded were examined with the goal of formulating predictive model for estimating quantity of infant-formula demanded. It was deduced that the distribution of estimated infant-formula quantity demanded are not equally distributed across tribes, maternal age groups, occupation types, literacy levels and qualification levels of breastfeeding mothers; and child age groups. The estimated infant-formula quantity demanded is equivalently distributed among different family structures, religion and parity. Negative binomial model was formulated for the estimated infant-formula quantity demanded as a function of breastfeeding duration. A positive association was found between the two and this is shown using the correlogram.

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