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Optimal Stocking Pattern of Chemical Fertilizers : An Application of the Waiting Time Model

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Abstract

Fertilizers are a crucial and vital input in crop production. 'Input dealer' is synonymously treated as 'Fertilizer dealer'. Given the high volume, high value of fertilizers, and the limitation of stocking space in relation to spurt in demand for fertilizers during growing season(s), the input dealers face the problem of deciding on optimal stocking pattern. This study addressed this crucial aspect considering the purchase pattern of different brands of fertilizers by farmers to determine the length of waiting time for fertilizer sale and optimal stocking pattern in Karnataka by using negative binomial distribution (NBD) and geometric distribution (GD). The retail purchase data (sales data) from the sale receipts of the retail outlet of Coromandel International Limited, Bada, Davangere, Karnataka, formed the database of the present study. The results indicated that NBD probability of purchase of fertilizer products varied from 0.35 to 0.62 depending upon the popularity of the fertilizer. The GD probability of purchase of any brand of fertilizer was 0.4, indicating that at least three farmers needed to visit the input dealer to get one unit of any fertilizer product sold. Both the NBD and GD were applied to find the optimal stocking pattern of fertilizers.

Keywords: **negative binomial distribution, geometric distribution, optimal stocking pattern, fertilizers, input dealers, inventorying**

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The central dry zone of Karnataka comprises of two districts, which are recognized as two of the three most disadvantaged ones (Murthy, Nagaraj, Chandrashekhar, Chandrakanth, Mahadevaiah, & Honnaiah, 2013) in Karnataka, namely Chitradurga and Davanagere, the other one being Bidar located in the North Eastern Transitional Zone. Agriculture is the main source of income of farmers in the three districts. The major crops are paddy, sugarcane, areca nut, groundnut, maize, millets, and oilseed crops (Official website of Davanagere District, Karnataka, (n.d) and Department of Agriculture & Cooperation, Ministry of Agriculture, GOI, (n.d)). The fertilizer demand crops are paddy, sugarcane, areca nut, maize, and oilseed crops (Food and Agriculture Organization (FAO), 2005). Chemical fertilizers form a crucial and vital component of input use in these crops. Due to the wide diversity of irrigated and rainfed crops in this zone, a wide variety of chemical fertilizers are being manufactured and supplied for the benefit of the farmers. Chemical fertilizer requirement varies inter alia with the soil condition, crop and its variety, season, income, awareness, and perception of the farmers. For input dealers, among other inputs, chemical fertilizers form the major proportion of their business in terms of weight, volume, and value. The popular chemical fertilizers supplied in these districts are those manufactured by Coromandel International Limited (CIL). The company has a retail outlet in the village Bada,

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Davangere. Five different chemical fertilizer brands (Coromandel International Limited, (n.d)) sold here are as follows :

(1) Complex fertilizer - Paramfos (16%N,20%P,0%K,13%S),

(2) Urea - Godavari (46%N),

(3) Zinc and Sulphur - Granu zinc (33%Zn and 18%S),

(4) Compound fertilizer - Godavari Di-ammonium phosphate (18%N and 46%P), and

(5) Aminoacid and proteins - Maximax.

Given the limitation of space, labor, and time, the optimal stocking of chemical fertilizers will be the sine quo non for their profitability. The other inputs such as seeds and agro chemicals are low volume, with low, medium, or high value, but fertilizers are both high volume and high value inputs. Hence, if optimal stocking pattern of fertilizers is decided, other inputs are relatively manageable due to their low demand for space and the business in the total turnover of input dealer/s. Thus, for a fertilizer dealer, given the space and capital limitations, it is crucial to find the optimal stocking pattern of different quantities of the five brands of fertilizers discussed above. This stocking pattern depends upon the popularity of different brands of fertilizers. Precisely, this is the objective of this study, proposed to be achieved with the application of the negative binomial distribution (NBD) as a waiting time model.

Significance of Optimal Stocking Pattern for a Fertilizer Dealer

Agriculture input dealers sell seeds, agro chemicals – chemical fertilizers, pesticides, insecticides, weedicides, fungicides, small agricultural implements, and face logistical constraints prominent in the peak agricultural seasons, especially during the south west and north east monsoons. Among all the agricultural inputs sold by the input dealers, due to the bulky nature of fertilizer products in relation to value, space, labour, and time limitations constrain the operations of the agriculture input dealers, for whom optimum stocking pattern is crucial and vital to improve the services to farmers, and also to improve their businesses.

This study provides a solution for optimal stocking pattern of chemical fertilizers, which are most often transacted by agriculture input dealers, and also form the bulk of their business in value terms. Many a time, if the proper supply of chemical fertilizers is not maintained, it leads to social tensions too due to a market situation somewhat characterized by 'very short period market,' where the supply becomes inelastic. However, due to administrative pricing of chemical fertilizers, the prices cannot behave like market prices. This puts additional institutional constraints on the logistics of the input dealer, while dealing with diverse farmers' diverse needs, which crop up at once during the sowing season/s. Hence, the economic significance of optimal stocking pattern is also suggested in this study.

Objectives of the Study

The objectives of the study are to :

(1) Estimate the purchase pattern of different fertilizers used by the farmers,

(2) Estimate the length of waiting time for fertilizer sale,

(3) Estimate the optimum stocking pattern of fertilizer brands.

Yule (1910), Greenwood and Yule (1920), Griffiths (1960), Chatfield, Ehrenberg, and Goodhardt (1966), Goodhardt and Ehrenberg (1967), Morrision and Perry (1970), Ehrenberg (1972), Paull (1978), and Chandrakanth, Gurumurthy, and Satakopan (1986) used NBD with the concept of waiting time. These are the only studies which have used the concept of negative binomial distribution (NBD) to find the popularity index of various products, thereby helping the retailers in stocking those products in an optimal manner.

Methodology

➲ **Data :** The retail purchase data (sales data) of chemical fertilizers by farmers were obtained from the sale receipts of the retail outlet of Coromandel International Limited, Bada, Davangere, Karnataka, for the period from October 2, 2011 to February 29, 2012, which included purchase of chemical fertilizers by 658 farmers who bought at least one of the CIL fertilizer products.

➲ **Assumptions :** The hypothesis of the study is that the purchase pattern of chemical fertilizers follows negative binomial distribution (NBD) to enable to move towards the optimum stocking pattern of fertilizers, given the floor space constraint. The NBD is based on independent Bernoulli trails, and it is assumed that each farmer's purchase is independent of other farmer's decisions. However, Leibenstein (1950) made a mention of the bandwagon effect (increased demand for a product is because of its popularity, but not because it is cheap or of better quality), the snob effect (decreased demand for a product because of its popularity, but not because it is costlier or is poorer in quality), and the Veblen effect (conspicuous consumption where demand increases though the prices are high) due to consumer demand. While these effects would hold good for wants, their effects would be modest on needs. Accordingly, as chemical fertilizers are serving the farming needs, the snob, Veblen, and bandwagon effects would be either modest or nonexistent.

This model is valid for a particular fertilizer dealer retailing fertilizer sales. Another assumption is that each fertilizer purchase is assumed to be different than the other, and even if a given farmer purchases fertilizers on different occasions, these are treated as two customers. The retail purchase pattern of a specific brand of fertilizer by farmers determines the stocking pattern. For the NBD, the number of units of a particular fertilizer product bought is denoted as 'success' and not buying as 'failure'. Thus, the total number of trails *'N'* consists of a number of buyings (or successes) 'r', and a number of non-buyings (or failures) *'x'* (so that the total number of trials $N = x + r$).

The negative binomial distribution provides for the probability of *'r'* number of purchases of a given fertilizer product (*r*th purchase materializing in the *N*th trail), and is given by :

$$P(x) = \binom{x+r-1}{r-1} p^r (1-p)x$$

For $x = 0, 1, 2, \ldots, r \geq 0 ; 0 \leq p < 1$

Here, p is the probability of purchase of one unit of the given fertilizer product. The procedure of fitting this distribution is outlined in standard statistical textbooks.

➲ **The Popularity Index :** The probability associated with success in this study is interpreted as indicative of the popularity index $p = \left(\frac{\bar{x}}{var(x)}\right)$ and this term is the popularity of the fertilizer product, which is assumed to determine its relative market share. Thus, if the NBD probability is large, then the market share of the fertilizer product is large, and the fertilizer product is construed to be popular. Here, probability indicates the popularity of that product, that is, of buying a fertilizer product by a farmer. The higher the probability, the greater will be the popularity, and the greater will be the market share.

Results and Discussion

For the purchase data distribution of five products, the features of NBD such as (a) the mean is less than the variance, (b) the chi square value for goodness of fit is insignificant, (c) the probability of least success (say, purchase of zero bags of the fertilizer product) is the highest, held good for all the five fertilizer products in this study.

➲ **Ranking of Products by Popularity Index :** The analysis revealed that the most popular product was Godavari urea with a popularity index of 0.62 with its highest nitrogen content among all other fertilizer products. This is followed by Complex fertilizer - Paramfos (16:20:0:13) having a popularity index of 0.59. The area is dominated by paddy based cropping system with other crops such as areca nut, maize, and sugarcane. The paddy farmers prefer Maximax, an organic product which induces more number of effective tillers, and thus, Maximax had a popularity index of 0.55. The fertilizer brand Granu zinc (33%Zn and 18%S) had the lowest popularity index of 0.35 (Table 1), as it is used in a limited way in the paddy field to supply zinc sulphate to cure Khaira disease.

The size of the popularity index has implications for the input dealers, that is, regarding the stocking pattern, given the input dealer's limited space and time at his/her disposal. Given the bulky nature of fertilizer products, space, labour, and time limitations constrain the operations of the fertilizer dealers, for whom optimum stocking pattern is crucial and vital for business and also for the services they are rendering, as discussed earlier. Hence, optimal stocking should reflect the stock of quantity of all products according to the probability of their purchase given by the NBD probability. Accordingly, by the time several units or quantities of the most popular product get sold, a few units of the least popular product will also get sold according to the popularity index, and therefore, the stocking pattern should reflect such a phenomenon.

➲ **Waiting Time for Specific Brand of Fertilizers to be Sold :** The waiting time in terms of the number of farmers to pass through the input dealer's shop, in order to get 10 units / bags of each of the fertilizer products sold is presented in the Table 2. Intuitively, the higher is the popularity, the greater is the demand for the product; and hence, the seller can sell it as early as possible. In other words, the higher the probability, the lower is the waiting time length and vice versa. In normal connotation, the waiting time is interpreted as the time elapsed between the time of registration of one unit of the product and the time of its delivery. In this study, due to constraints of data, the "length of waiting time" is modified to mean the number of customers ($N=x+r$) required to visit the input dealer to get the required quantity or number of bags ($r=10$) of a particular fertilizer product sold, with the assumption that

Table 1. Fertilizer Products Ranked According to their Popularity Index

Sl No.	Products	Popularity Index
1	Urea - Godavari (46%N)	0.62
2	Complex Fertilizer - Paramfos (16% N, 20% P, 0%K,13% S)	0.59
3	Amino acid and protein - Maximax	0.55
4	Compound fertilizer - Godavari Di -ammonium phosphate (18%N and 46%P)	0.49
5	Zinc and Sulphur - Granu Zinc (33% Zn and 18% S)	0.35

Table 2. Length of Waiting Time in Terms of Number of Customers Required to get *'r'* Bags Sold

Fertilizer Products	Waiting time *(N)* farmers required to visit the input dealer's shop to get *r* = 10 bags of fertilizer product sold
Urea - Godavari (46% N)	16
Complex fertilizer - Paramfos (16% N, 20% P, 0% K, 13%S)	17
Amino acid and Protein (Maximax)	18
Compound fertilizer - Godavari Di-ammonium phosphate (18%N & 46%P)	20
Zinc and Sulphur- GranuZinc (33%Zn and 18%S)	29

the probability associated with success remains constant for all the units in a given agricultural year. The length of waiting time is, therefore, obtained by dividing the desired number of a particular fertilizer (units or bags) to be sold by the popularity index (p).

Accordingly, the higher is the popularity of the product, the lower is the waiting time in terms of the number of trails (farmers) required to visit the input dealer's shop to get 'r' units or bags of the product sold. Accordingly, the most popular product being the Godavari urea, it had the lowest waiting time.

➲ **Waiting Time for Any Brand of Fertilizer to be Sold :** The theoretical distribution for determining the probability of at least one of the five products to be sold is the 'Geometric Distribution' *(GD)*, which is a particular case of the NBD. The geometric probability distribution is given by $p(y) = p\ (1- p)\ y$, where Exp $(y)= (1- p)/p$; Var $(y) = (1-p)/ p^2$ and p = mean/variance is the probability that at least one fertilizer product will be purchased at a time, and thus $y = 0, 1, 2, 3, 4, 5$ in this case. Accordingly, it is estimated that in general, the products of CIL have a 0.4 *GD* probability that at least one of the five fertilizer products will be bought. In terms of 'waiting time,' it would be that (1/0.4=) 3 farmers must visit the input dealer's shop of whom one will purchase at least one fertilizer product out of the five sold in the shop.

➲ **Stocking Pattern and Implications for Storage Costs :** As an input dealer, the importance of the proportion in which different fertilizer products would be stocked is already outlined. Furthermore, an optimal stocking pattern shaped by the purchase pattern of farmers will reduce the costs of storage and will also attract the marginal customer. If the input dealers just pile up the stocks of different agriculture inputs without regard to their sales probability, this drains the space and time of the dealers by way of keeping an unsold stock or inventory over time, thus adding to the cost of storage and grabbing the space which could be devoted to other agricultural inputs, which are essential to farmers from time to time in an agricultural year. Furthermore, if the input dealer does not keep products (including some least popular products) in small quantities according to the NBD probability, some farmers may turn away disappointed, and may hesitate to visit the input dealer's shop for other purchases in the future, since, in general, farmers prefer to make purchases from a dealer's shop wherein most of the agricultural inputs are available.

➲ **Optimal Stocking Pattern :** This optimum stocking pattern is determined on the basis of the 'popularity Index' *(p)*. The proportion of the probability of one of the fertilizer products is taken with the probability of all other products. Accordingly, if an input dealer wishes to sell all the five products of CIL, then, out of every 100 bags of different fertilizer brands, he/she has to keep 13 bags of Granuzinc, 19 bags of Godavari Di-ammonium phosphate, 21 bags of Maximax, 23 bags of Paramfos, and 24 bags of Godavari urea. That is, for every 1 bag of GranuZinc, the dealer should keep 2 units of Godavari urea because by the time 1 bag of GranuZinc is sold, 2 bags of Godavari urea would have been sold. Thus, NBD also provides guidelines for the pattern of maintaining stocks based on the purchase pattern of farmers.

Implications and Conclusion

As the input dealers are constrained with time, labour, space and capital, the optimal stocking of inputs based on their popularity index is a sin quo non for maximizing profit. Since CIL has a retail outlet, the information on the popularity index will also educate the manufacturer in scheduling the production level of various inputs/products. The optimal inventorying of fertilizer products certainly reduces the storage cost, and in turn, attracts the marginal customer. It also educates the dealer in stocking those fertilizer products that are demanded in lesser quantity and facilitates in counteracting the disappointment and hesitation of the customers in visiting the retail outlet.

This study offers normative solutions to dealers of agriculture inputs regarding the optimal stocking pattern of different brands of agriculture inputs to be inventoried in their store depending upon the negative binomial probability of purchase of the agriculture inputs. Different types of fertilizer products were considered for analysis purposes, and the methodology can be extended to cover major agriculture inputs to facilitate the input dealer to offer a wide range of solutions. The NBD probability of purchase of fertilizer products varied from 0.35 to 0.62 (Table 1) showing different shades of popularity of the fertilizer products. The geometric distribution probability of purchase of any brand of fertilizer was 0.4, indicating that at least three farmers need to visit the input dealer to get one unit of any fertilizer product sold. Thus, both the negative binomial and geometric distributions have useful applications in determining the optimal stocking pattern of agriculture inputs. On the one hand, this application is hoped to provide immense economic value to the input dealers (to take care of their stocking pattern), and benefit the farmers on the other hand.

Limitations of the Study and Scope for Further Research

NBD estimation holds good for particular dealers who are retailing in fertilizer sales. In the analysis, each fertilizer purchase is treated as a distinct and different unit. The farmer purchasing more than one unit of products is treated as a separate customer. If the data set fails to follow negative binomial distribution, that is, variance in the data set is lesser than its average (mean), and chi square statistic of goodness of fit is significant, then the popularity index for fertilizer products cannot be obtained and the policy pertinent to optimal stocking or inventorying cannot be implied.

The above model can be extended to analyze the agriculture inputs which are always in short supply in relation to demand. Assuming that only *'r'* units of a particular input are available and if *'p'* is the probability that one unit is sold to a farmer, we can find out the probability that there will be an excess demand say for *'M'* units, and what is the expected demand - supply gap, *E(M)* for the particular agro input in question. These factors are of a considerable importance to an input dealer and for entrepreneurs. Waiting time length can also be estimated in terms of the number of days *(N)* required for getting specified units *(r)* of a product sold. The popularity index can be considered as a function of the crops, seasons, and other relevant factors, and a regression analysis would highlight the relative importance of these variables.

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