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# Optimal price markup policy for an inventory model with random price fluctuations and option for additional purchase

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ABSTRACT

In this paper, based on the analysis of empirical data of dealer and retailer prices and sales of cement – as a prototype of functional products – we develop a probabilistic inventory model for the situation when dealer′s selling price fluctuates and affects the retailer′s selling price. Demand is a function of price markup and retailer′s purchase price. Dynamic price markup policy is proposed and optimal length of replenishment cycle and order quantity is obtained. Concavity of the profit function with respect to price markup is discussed. A procurement policy which considers opportunity of purchase at a low price before the end of the optimal replenishment cycle is proposed and compared with other policies. Algorithm, numerical examples, sensitivity analysis and managerial insights are presented.

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## 1. Introduction

Products which have long product life cycle (PLC) and low demand uncertainty, like groceries, casual readymade garments, cement and other building materials, are termed as functional products. These are characterized by exogenous random fluctuations in dealer price (DP), stable demand and low profit margin (Fisher, 1997). Due to heavy competition, demand for such products mainly depends upon the retailer′s selling price (RSP). As the retailer′s purchase price (RPP) is not under the retailer′s control, the end user demand depends mainly on his price markup (PM) or sometimes, the markup proportion. Unlike those competitive situations where retailer may use pricing to control demand, the only control that can be exercised by the retailer on the demand for functional products is a careful choice of a competitive PM.

Many retailers follow the retail fixed markup (RFM) policy of charging a fixed amount over and above the dealer selling price (DP) (Liu et al., 2009). However, practical observations indicate that (1) generally retailers replenish inventory for weeks or months, during which DP may fluctuate to values above or below the RPP; (2) retailer is governed by the business ethics that "on any day, RSP cannot be below the DP"; (3) when the DP on a day is lower than the RPP, the retailer may have to sell at a low markup; (4) retailer will not sell below his purchase price. Hence in the presence of fluctuating DP, RFM may not always be practical.

In order to develop a realistic model based on which we can suggest price markup strategies to a retailer of a functional commodity in India, we have collected empirical data of price (Fig. 1) and sales (Fig. 2) of cement as an important prototype of functional product, from a retailer located in Indore (India).

We have analyzed the collected data to gain insights into the important factors in order to build a viable model and made an attempt to work out the best ordering and pricing options for the retailer. Statistical analysis of the empirical data shows that the dealer prices follow two parameter exponential distribution with location parameter $\gamma=200$ and inverse scale parameter $\lambda=0.08$ ($P$-value of Kolmogorov–Smirnov test statistic is 0.76436).

We were informed that the retailer places order every week, whereas analysis of the sales data of cement, using autocorrelation function and partial autocorrelation function, indicates that during a quarter, the series is stationary. In view of this, and the support of deterministic demand as an approximation to probabilistic demand by Netessine (2006), we consider the demand to be deterministic if length of the planning horizon is such that demand is not affected by seasonal variations.

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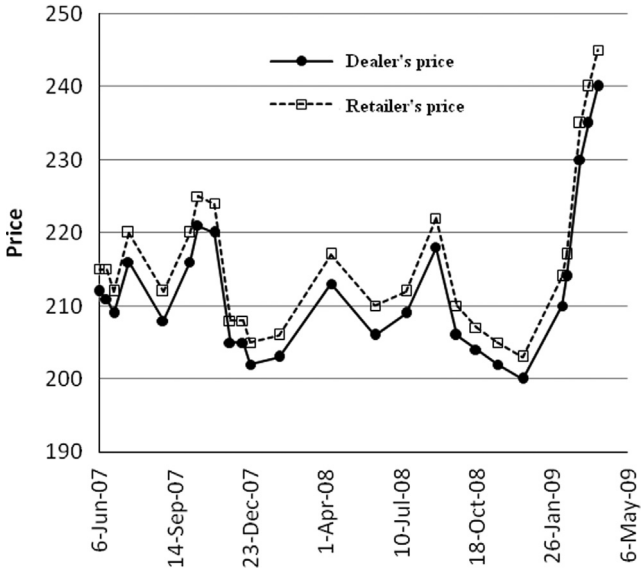


**Fig. 1.** Dealer's and retailer's price of cement (per bag).

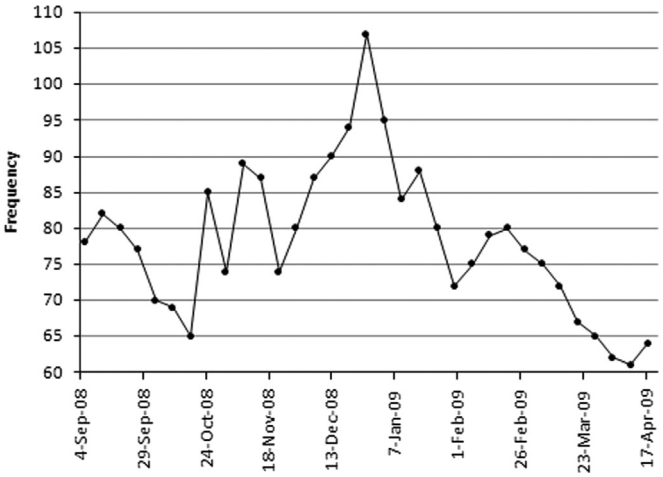


**Fig. 2.** Sales data of cement for a retailer in Indore.

Before going on to the model and its optimization aspects, we present some of the literature related to various aspects of the model considered in this paper viz. a diversity of types of demand functions, pricing decisions and effect of change in price (selling or purchase price) on the demand rate. Time dependent demand is considered in inventory models by Urban and Baker (1997), Teng and Chang (2005), Banerjee and Sharma (2008, 2009, 2010), Bitran and Mondschein (1997), etc.

Various authors consider pricing as a means of control over demand. For the newsvendor type problem, Petruzzi and Dada (1999) provide an excellent review with extensions. Other researchers have also considered price dependent demand (Chen et al., 2006; Lau and Lau, 1998, 2003; Polatoglu, 1991, Avinadav et al., 2013). Elmaghraby and Keskinocak (2003) give a comprehensive review of the literature and practices in dynamic pricing.

Continuous change in purchase price was considered by some authors. Among them, Erel (1992) considered a compound increasing unit cost due to inflation during a finite planning horizon while Khouja and Park (2003) proposed an extension of EOQ that can be used when unit cost is decreasing. Khouja et al. (2005) developed the joint replenishment problem to analyze the effect of continuous decrease or increase in unit purchasing cost on the optimal ordering frequencies. Arnold et al. (2009) used deterministic optimal control approach for optimizing the procurement and inventory policy of an enterprise that is processing a raw material when the purchasing price, holding cost, and the demand rate fluctuate over time. Banerjee and Meitei (2010) consider linearly declining selling price for the single period problem. Gavirneni (2004) considered periodic review policy for the inventory model where the purchase price of the product undergoes a Markovian transition from one period to the next. However, in Gavirneni's model the purchase price can take values only from a finite set and the selling price is fixed whereas in practice, RSP often fluctuates due to exogenous factors (e.g., DP) and/or endogenous factors (e.g., PM). PM is one of the major tools often used by retailers for setting selling price. For a detailed discussion on PM one may refer to Liu et al., (2009).

In addition to the observations at the beginning of this section regarding demand and price of functional commodities, a common observation is that fluctuating DP may result in fluctuating RSP. If DP falls below the RPP, the retailer may have to sell at a low markup but will still be at a disadvantage since he has to sell at a higher RSP compared to those retailers who purchased at a low RPP and hence sell at a lower RSP thereby generating higher demand. On a positive note, it lends the retailer an opportunity to purchase the commodity at a

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