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ISSN: 2513-2504

INVENTORY DECISIONS UNDER STOCHASTIC DEMAND SCENARIO WITH HIGH INFLATION RATE-ML APPROACH

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ABSTRACT – Hyperinflation is a situation where prices increase at an average monthly rate of 50% or more, leading to a rapid loss of the currency's value and causing severe economic problems. Inventory decisions under hyperinflation are crucial due to the high level of uncertainty and the rapid increase in prices can lead to significant losses if inventory is not properly managed. We examine the effects of hyperinflation on inventories of Biscuits and develop an ML model to forecast optimal order quantities of Biscuit products, with the intention of lowering inventory holding costs and inventory deterioration. Data from a retail company in Sri Lanka during the hyperinflation period of 2022 have been used to develop the ML model to predict customer demand. Six ML techniques were utilized to achieve the research objectives. Root Mean Squared Error (RMSE) and R-squared metrics are employed to choose the best model. We find that Random Forest is the most appropriate ML model to forecast optimal order quantities during a hyperinflation situation. The outcomes of our study will aid professionals working in the Biscuit industry to effectively handle inventory management during periods of hyperinflation. Our ML model can serve as a fundamental tool for predicting inventory levels during hyperinflation, which can be used as a starting point for further analysis.

Keywords: Demand Forecasting; Hyperinflation; ML; Inventory Decisions

1. INTRODUCTION

Effective inventory management is critical in supply chains as it encourages collaborative relationships with suppliers and customers by balancing demand and supply. The primary function of inventory is to ensure the smooth flow of products, and to achieve this, firms must consider both upstream supplier interactions and downstream customer demands. Therefore, customer demand is one of the most critical variables in Inventory Management [1]. It is important to make sound inventory decisions when faced with stochastic demand, particularly in an unstable market environment characterized by fluctuating customer demand.

High inflation is a significant macroeconomic variable influencing stochastic demand. Sri Lanka's hyperinflation in 2022 led to a substantial reduction in citizens' purchasing power due to uncontrolled price increases. The biscuits and related food products industry in Sri Lanka was severely affected with the cost of essential raw materials such as wheat flour, vegetable oil, and sugar skyrocketing by approximately 200% within months [2]. There has been a significant increase in the prices of biscuits, leading to a decrease in consumption. This has resulted in an excess inventory buildup for both manufacturers and retailers, causing substantial financial losses. In such situations, accurate demand forecasting is crucial for organizations to minimize their losses while satisfying customer demand.

In this context, we attempt to fill this research gap by examining the impact of hyperinflation on Biscuit product inventories and developing a machine-learning model for retailers to predict optimal order quantities during periods of economic instability.

ISSN: 2513-2504

2. MATERIALS AND METHODS

2.1. Dataset and Preparation

Our study is based on a dataset gathered from a retail shop situated in Sri Lanka during the year 2022. The dataset consists of monthly sales and price data of 16 different stock-keeping units (SKUs) of biscuits. The data set was divided into two subsets: 80% for training and 20% for validation. It is pertinent to note that the inflation rate in Sri Lanka during the study period ranged from 14.1% to 69.8%. The decision variables used in the study were the inflation rate and the price of the SKU. These variables were utilized to predict monthly demand. For the study, the sales data was assumed to be the demand data of the SKU under consideration.

To normalize the SKU data separately, the following equation was employed. X, x min, x max indicates original value, minimum value in the range, maximum value in the range respectively.

$$x' = \frac{X - Xmin}{Xmax - Xmin}$$

Equation 1. Normalization

2.2. Machine Learning Methods

Based on an extensive review of the literature, it has been determined that ML models, including Linear Regression (LR), K Nearest Neighbour Regression (KNNR), Support Vector Regression (SVR), Decision Trees (DT), Random Forest (RF), Adaptive Boosting, XG Boosting and Statistical models such as FB Prophet and Interrupted Time Series (ITS) employing Ordinary Least Squares (OLS) exhibit potential for predicting product demand.

As per the demand pattern of Biscuit SKUs, we have identified that ITS using OLS and LR cannot be implemented as both models assume linearity and our data set does not have a linear nature. Further, FB Prophet is also not appropriate as it relies on extensive historical data, which we lack for our analysis as we had monthly demand data for 2022. Therefore, we have conducted a comparative analysis of the rest of the six ML techniques which are SVR, DT, RF, KNNR, Ada Boosting, and XG Boost. Among the models considered in the literature, RF, XG Boost, and Adaptive Boost were identified as the best performing ML techniques according to the ratings given by the authors in their respective AI domains [3].

3. RESULTS AND DISCUSSION

According to our initial analysis, we identified that prices of all SKUs start to increase by approximately 68% when the inflation rate in the country reaches approximately 50%. Our results show that there is no significant impact of hyperinflation on the sales of small SKUs, as some SKUs exhibited an increasing trend of sales, while others remained relatively stable. 16 smaller SKUs demand pattern were analyzed and 87.5% of them were not affected by the hyperinflation. During hyperinflation, customers tend to switch from purchasing larger SKUs to smaller ones due to the comparatively lower prices of the latter. This shift in preference is driven by the desire for financial stability and maximizing purchasing power as hyperinflation diminishes the value of currency. Opting for smaller SKUs allows customers to maintain affordability and obtain essential items despite the challenging economic conditions.

On the other hand, large SKUs experienced a severe decline in sales due to hyperinflation, with a significant drop observed as prices increased. Consequently, a benchmark size of 100g was established, to separate larger SKUs and smaller SKUs. Models were developed and implemented solely for SKUs that were equal to or larger than 100g.

Table 1. Machine Learning Methods

SVR	0.149	82.71
RF	0.095	93.05
Adaptive Boosting	0.105	91.46
XG Boosting	0.099	92.40
DT	0.105	91.47

The outcomes obtained from ML models are summarized in Table 1. Through our analysis, we identified that the Random Forest model, which is a tree-based ensemble technique, exhibited superior performance, boasting the lowest RMSE and achieving the highest R squared value. RMSE measures the average distance between the estimated and the actual values in the same units as the original data. R-squared (coefficient of determination) indicates the proportion of the variance in the dependent variable that is predictable from the independent variables.

4. CONCLUSION

We study the impact of hyperinflation on demand for Biscuit products using a real-world data set from a retails shop in Sri Lanka. The initial analysis indicates that larger SKU sizes are more affected by hyperinflation due to higher prices. Hence, we advise Biscuit industry practitioners to prioritize producing smaller SKUs during hyperinflation to manage inventory more effectively and maximize profits in uncertain times.

Further, we implemented six ML models to predict demand for larger biscuit SKUs for retailers and compared their performance using RMSE and R-squared values. The results demonstrate that the Random Forest model is the most suitable for demand forecasting in this specific context. The ML model developed in this research can serve as a foundational tool for further academic research on inventory forecasting under such economic conditions.

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