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FORECASTING SESAME PRICE USING KALMAN FILTER ALGORITHM

TESFAHUN BERHANE[1,*], MOLALIGN ADAM[1], NURILIGN SHIBABAW[1], AEMIRO SHIBABAW[1], ABERA A. MUHAMED[2]

[1]Department of mathematics, Bahir Dar University, Bahir Dar, P.O.Box 3018, Ethiopia
[2]Department of mathematics, Kotebe Metropolitan University, Addis Ababa, P.O.Box 31248, Ethiopia

Abstract. This study aims at forecasting the white Humera Gondar sesame class 4 (WHGS4) price in Ethiopia. We used the daily closed price data of Ethiopian sesame recorded in the period 2 January 2012 to 30 March 2018 obtained from Ethiopia commodity exchange (ECX) to analyse the price of sesame. We applied the Kalman filtering algorithm on a single linear state space model to estimate and forecast an optimal value of sesame price. We used root mean square error (RMSE) to evaluate the performance of the algorithm for estimating and forecasting the sesame price . Based on the linear state space model and the Kalman filtering algorithm, the root mean square error (RMSE) is 0.000001877 , which is small enough, and it indicates that the algorithm performs well.

Keywords: WHGS4 sesame price; forecasting; state space model; Kalman filtering algorithm.

2010 AMS Subject Classification: 62P05, 97M30.

1. Introduction

Sesame is one of the oldest oilseed crops and is cultivated in tropical and subtropical regions of Asia, Africa and South America [10]. Ethiopia is among the top five world's producers of sesame seed [4]. In Ethiopia, the production of sesame is both by small and large scale farmers;

*Corresponding author
E-mail address: tesfahunb2002@gmail.com
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and it is an important crop and export commodity. The total area, production and productivity during 2013 were 0.299 million hectare, 0.220 million tonnes and 0.735 tone per hectare, respectively; and the total area and production were increased by 61.23 % and 17.91 %, respectively [2]. Ethiopia has a large number of different sesame varieties, including the Humera, Gonder and Wellega varieties, which well known in the international market. The major sesame growing areas are found in the locations of Humera, Metema, Benshungul Gumuz and Wellega [5]. Sesame is the second largest export crop in Ethiopia next to coffee, and accounts for over 90% of the value of oil seeds exports[4]. And it is the third largest exporter of sesame seed after India and Sudan[1]. Ethiopia has been significantly increasing its supply to world markets from 1998 to 2005/06. Its annual total exported quantity increased from 50,000 to 150,000 tonnes, which is a threefold rise in eight years time[3]. The main importers of Ethiopian sesame are China, Israel, Turkey, Japan and other European countries [7]. It contributes the highest market values from the oilseeds exports. Thus, Sesame plays a major role for the development of Ethiopian economy.

Sesame production varies from year to year due to weather conditions, diseases, traditional production system, low productivity varieties and others. These have great impact on sesame market. And it is unstable and characterized by wide fluctuations in price. This price fluctuation has great effect on farmers' livelihood and it makes difficult for them to predict their income for the coming season. Therefore, it is of great significance to develop a model to forecast the sesame price to reduce the risks associated with White Humera Gondar Sesame Grade four (WHGS4) price fluctuations.

There are previous studies related to price forecasting problems. For instance, ARIMA and GARCH models are applied to model and forecast the volatility of the price of Ethiopian sesame. These models are employed to analyze the price fluctuation of monthly recorded sesame data which is obtained from National bank of Ethiopia and Central statistical agency [6]. Kalman filtering algorithm is suitable in the study of multi variable systems, time varying systems and random processes. Kalman filtering algorithm is used to forecast highly fluctuated and time varying stock market price [9]. More over, this algorithm was also applied to forecast the Ethiopian coffee price and it performed well to obtain an optimal value of coffee price [8].

As per the knowledge of the authors, there is no mathematical model that has been developed for estimating and forecasting sesame price in Ethiopia. Therefore, in this paper we use a linear model in state space form which we estimate using Kalman filter. The paper is organized as follows: section 2 analysis of sesame price, in section 3 we describe the Kalman filter, section 4 result and discussion and section 5 conclusion.

2. Analysis of WHGS4 sesame price data

The daily closed price of Ethiopian sesame from January 2, 2012 to March 30, 2018 recorded by Ethiopia commodity exchange (ECX) market is considered to study sesame prices movements see figure 1

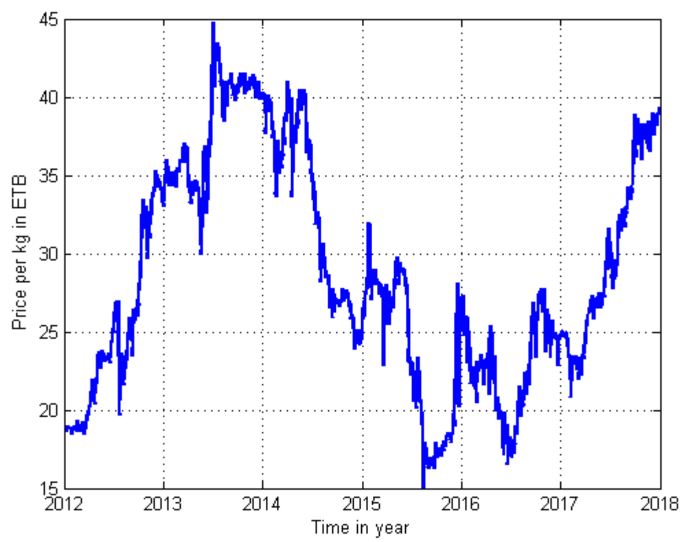

Figure 1. The WHGS4 price from 2012 to 2018

Figure 1 shows that the sesame price gradually increases since the beginning of 2012 and reached a peak price of(attain maximum price) 41.50 ETB(Ethiopian Birr) at the middle of 2013 and then after the price decreases step by step and fall down to a minimum price of 15.00 ETB at the end of 2015. Again from the beginning of 2016 to the middle of 2017 there were ups and downs in the price of sesame. Finally, the sesame price shows an increasing pattern since the end of 2018. In general the sesame price plot shows that the price does not have any seasonal pattern.

3. The Kalman filter

The Kalman filter is a recursive algorithm that is used to find an optimal estimation of the state of a time-varying system and non-stationary random processes which is indirectly observed through noisy measurements. Kalman filtering theory set out to extend Wiener filters to non-stationary processes. The formulation is not very much more complicated than for Wiener theory. It is recursive so that new measurements can be processed as they arrive. The Kalman filter algorithm has two step process:prediction and update steps. In the prediction step, the Kalman filter calculates estimates of the current state variables and the error covariance to obtain a prior information for updating step. In updating step, the Kalman filter tries to incorporate the next new measurement in to the prior estimate to obtain an improved posterior estimate. For the Kalman filter, the stochastic process must be represented in a state space formulation. This representation consists of a transition equation to describe the evolution of the state variables over time and a measurement equation to relate the state variables to the observable data.
Consider the dynamic system

$$x_k = Ax_{k-1} + q_{k-1} \tag{1}$$

$$y_k = Hx_k + r_k \tag{2}$$

where A is the state transition matrix, H is the measurement matrix, q_{k-1} is the model noise, x_k is the state vector, y_k is the measurement vector, r_k is the measurement noise, q_{k-1} and r_k are the independent white noises with zero mean, and their variance matrices are Q and R respectively. Here, our aim is to study a single time series sesame price data, this means that the state transition matrix A is one, and it indicates that the sesame price at time k is the same as the price at time $k-1$ plus the random shock. Also, the measurement matrix H is one. Then equation 1 and 2 can be expressed as

$$x_k = x_{k-1} + q_{k-1} \tag{3}$$

$$y_k = x_k + r_k \tag{4}$$

The system 3-4 represents the state space model of sesame price. The aim of estimation of the state is to get the optimal price estimator value from observed price, by taking the first observed value as initial expectation of state variable and the variance of the first difference of the observed data as initial covariance P_0. The shock term q_{k-1} is random white noise, so its expectation is zero and variance is Q . Here, the initial value of state variable is zero, the expectation of state variable is 19.30, and the covariance is 0.62464. The measurement equation is aimed to relate the state variables to the observable data and the term r_k is a white noise that is its mean zero and covariance $R = 0.01$.

The prediction equation of sesame price is given by

$$\begin{aligned} E[x_k/k-1] &= E[(x_{k-1}+q_k)/k-1] \\ &= E[x_{k_1/k-1}] + E[q_{k-1/k-1}] \\ m_k^- &= E[x_{k-1/k-1}] \\ m_k^- &= m_{k-1} \end{aligned} \tag{5}$$

Where E is expectation, m_k^- is predicted mean. Forecast error, which is the difference between observed value and the forecast value is:

$$V_k = y_k - m_k^- \tag{6}$$

This difference, v_k is usually called innovation and it plays a vital role in the Kalman filtering algorithm specially to extract all useful information as far as possible. And, its variance is given by

$$S_k = P_k^- + R \tag{7}$$

The covariance of prediction-estimation, S_k is measurement prediction covariance, P_k^- is predicted covariance. The covariance of prediction-estimation error is given as

$$P_k^- = P_{k-1} + Q \tag{8}$$

The Kalman gain matrix equation that minimizes the covariance of the filtering prediction error is

$$K_k = P_k^- S_k^{-1} \tag{9}$$

The sesame price equation of Kalman filtering estimation is:

$$m_k = m_k^- + K_k V_k \tag{10}$$

The covariance equation of Kalman filtering estimation is:

$$P_k = P_k^- - K_k P_k^- K_k^t \tag{11}$$

For the state equations 3 and 4, the Kalman filter prediction and update steps are given as

Prediction step:

$$\begin{aligned} m_k^- &= m_{k-1} \\ P_k^- &= P_{k-1} + Q \end{aligned} \tag{12}$$

Update step:

$$\begin{aligned} V_k &= y_k - m_k^- \\ S_k &= P_k^- + R \\ K_k &= P_k^- S_k^{-1} \\ m_k &= m_k^- + K_k V_k \\ P_k &= P_k^- - K_k S_k K_k^t \end{aligned} \tag{13}$$

4. RESULT AND DISCUSSION

In this study, we use daily recorded sesame price from 2 January 2012 to 30 March 2018 from the Ethiopian Commodity Exchange. The results show that one-step forecasting of sesame price using Kalman filtering algorithm is efficient. Sesame price is analyzed based on the price itself. Figure 2 shows that Kalman filtering algorithm performs well to estimate the sesame price. According to the linear state space model and the Kalman filtering algorithm, the root mean square error(RMSE) is 0.000001877, which is small enough, and it indicates that the algorithm

FIGURE 2. Observed value and estimated value by Kalman filtering

performs well. Based on the linear state space model and Kalman filtering algorithm, we are able to forecast the WHGS4 sesame price on 30 March 2018. Accordingly, the forecasted value of sesame price on the specified date is 39.29 ETB per kg and the actual sesame price on the same date is 39.30 ETB per kg. As a result, the forecasting error is too small. In general, the above result indicates that the algorithm is effective in forecasting one-step sesame price.

5. Conclusion

We used the Kalman filter Algorithm to analyze the WHGS4 sesame price. Through continuous prediction and updating, the algorithm estimates the sesame price with a minimum error. Moreover, we forecast the sesame price for 30 March 2018 and the forecasted value of sesame price on the specified date is 39.29 ETB per kg and the actual sesame price on the same date is 39.30 ETB per kg, which is a very good estimate. In general, the Kalman filtering algorithm is applied in the field of estimating and forecasting sesame price and can be widely used for prediction of other commodity prices.

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Conflict of Interests

The authors declare that there is no conflict of interests.

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