مجلة البحوث المالية والتجارية
المجلد (23) – العدد الثاني – إبريل 2022

التنبؤ بالرقم القياسي لأسعار المستهلك المصري في زمن جائحة كورونا باستخدام سلاسل ماركوف الموزونة

Predicting the Egyptian Consumer Price Index in Covid-19 Pandemic using Weighted Markov Chain

Maha Farouk[1] , and Nasr I. Rashwan[2]

[1,2] Department of Statistics, Mathematics and Insurance- Faculty of Commerce – Tanta University, Tanta-Egypt.

Maha.ibrahim@commerce.tanta.edu.eg , nasr.abouzaid@commerce.tanta.edu.eg

https://jsst.journals.ekb.eg/ :رابط المجلة

الملخص

يتسبب فيروس كورونا في مرض معد هوٍ (كوفيد –19) ، الذي يقلل من القوة الشرائية للناس كما أنه يقلل من النمو الاقتصادي للبلاد. لذلك – في زمن جائحة كورونا– يعد التنبؤ بمؤشر أسعار المستهلك في مصر والذي يشار إليه عادة لشرح آثار الجائحة على التنمية الاقتصادية المصرية هو أمر مهم للغاية. هدفت هذه الدراسة إلى التنبؤ بالاتجاه قصير المدى لمؤشر أسعار المستهلك المصري باستخدام سلسلة ماركوف المرجحة (WMC) في في زمن جائحة كورونا مع أخذ بيانات مؤشر أسعار المستهلك القومي من (فبراير 2020) إلى–يوليو 2021 كمثال. تم اقتراح مخطط ترجيح (اوزان)جديد للتنبؤ بمؤشر أسعار المستهلك وفقًا لنموذج سلسلة ماركوف الموزونة. أظهرت نتائج البحث في التنبؤ حول مؤشر أسعار المستهلك هي كما يلي: في أغسطس 2021، كان مؤشر أسعار المستهلك = 114.85 بنسبة مئوية للحدوث 79.15٪ وفي سبتمبر 2021 مؤشر أسعار المستهلك = 116.785 بنسبة 79.76٪.

الكلمات المفتاحية: سلسلة ماركوف الموزونة، كوفيد– 19، مؤشر أسعار المستهلك، التنبؤ والتحليل

Abstract

acute respiratory syndrome coronavirus is caused an infectious disease (Covid-19), which decreases the people's purchasing power. It also decreases country's economic development ingrowth indicates. Therefore- in Covid-19 Pandemic- predicting consumer price index occurs commonly referred to explain its effects on the Egyptian's economic development is very important. This study aimed to predict short-term trend of Egyptian consumer price index using weighted Markov Chain (WMC) in Covid-19 Pandemic taking the national consumer price index data from (feb2020) to -July 2021 as an example. A new weighting scheme to predict consumer price index under weighted Markov chain model was proposed. In predicting Researchers' findings on the consumer price index are as follows: in Aug 2021 CPI =114.85 has a 79.15% chance and in Sep 2021 CPI = 116.785 has a 79.76% chance.

Keywords: Weighted Markov Chain, Covid- 19, Consumer Price Index, forecasting and analysis

1. Introduction

During 2019, Covid-19, a new type of coronavirus, was discovered in Wuhan, Hubei, China. Since that, it spreads widely all over the world This has resulted in a global pandemic that has persisted until now. Covid-19, in general, caused many losses on the Egyptian economy because of its enormous impact and it has become a big concern of the people.

Price index (CPI) in Egypt is defined by the Egyptian Central Agency for Public Mobilization and Statistics (CAPMAS) as an index used to compute the average change price from a collection of goods and services in a month, which consumed by households and residents within a certain month (El-Sheikh, (2013)). (CPI) is a key economic statistic. because it can provide further details about developments in the price of goods/services that paid in an area by customers. (CAPMAS) usually measure Inflation based on (CPI) indicator. To determine the changes in a fixed group of goods/services with a fixed price that are commonly consumed by locals, CPI calculation is intended.

At present, in economic forecasting, there are many forecasting methods based on absolute distribution such as Weighted Markov chain method .it has high reliability and reasonable and has sufficient information utilization as the characteristics of wide forecasting range (Qing-Xin (2015)).

In the financial world, the weighted Markov chain is commonly employed because in predicting something It needs some recent data and does not require long and continuous historical data. Therefore, it may be used to solve a wide range of economic challenges, as the consumer price index. so, using weighted Markov chain in predicting was the aim of many studies such (Zhihang et al ,2010), the research predicted the future incidence state using weighted Markov chain, (Zulfiqar and colleagues, 2018). The research introduced a new weighting scheme for estimating the probability of drought episodes in a Weighted Markov model, (Kafi et al. 2019) compared the weighted Markov chain and the fuzzy time series Markov chain in forecasting firm X's stock closing price, also Obasohan (2020) compared the weighted Markov chain and the Auto-Regressive Integrated

Moving Average in predicting annual closing rates of under-5 mortality in Nigeria, (Sun, (2020)) used a weighted Markov chain model to examine and forecast the Shanghai Composite Index's short-term trend, and When faced with Pandemic Covid-19, (Indah et al (2021) employed a weighted Markov chain to anticipate consumer price index, and for estimating sales demand in a corporation, (Martina, 2021) employed a multivariate Markov Chain model.

Because of the many variables that influence the average change in the consumer price index over time during the Covid-19 Pandemic, and because these changes are sometimes unpredictable, this study used a weighted Markov chain to anticipate the Egyptian consumer price index. (CPI) from (Aug2020) to (Sep2021).

2. Method of Markov process:

Markov process is a kind of random process without after effect used to predict the dynamic system with random change. The basic characteristic of Markov chain, it indicates that the state at time n+1 is only related to the state at time n, independent of the state before time n (Qianhong, 2020)

The Markov chain is a method for analyzing the current behavior of numerous variables in order to predict the future behavior of the same variable. It forecasts the system's future evolution based on the likelihood of transitioning between states. With time T = (0,1, 2), a Markov process with a finite set state space. is called Markov chain with discrete time. The weighted Markov process, from a random time series, describes the process of dynamic change and study the state of objects, transition states. the initial state weight is the difference between it and the Markov chain method.

1. **The Markov chain can only be used to model a process if it has Markov qualities. (Sun, 2020).**
2. **The state space of** $(X\colon n \geq 0) \mathit{is\ countable\ set}$

As long as P $[(\mathbf{X_0} = \mathbf{i_0}), \ldots, (\mathbf{X}_n = \mathbf{i}_n)] > 0$**Markov formula to calculate the state transition probability matrix,**

$$\mathbf{P\{X_{n+1} = j \setminus X_0 = i_0, \cdots, X_{n-1} = i_{n-1}, X_n = i\} = P\{X_{n+1} = j \setminus X_n = i\}},$$

for all states $i_0, \ldots, i_{n-1}, i, j$, and all n times. (Indah et al (2021))

To determine whether or not the process exhibits Markov qualities, a χ^2 statistical test will be used, when m = number of states

$$\chi^2 = 2\sum_{i=1}^{m}\sum_{j=1}^{m} f_{ij}\left|ln\frac{\hat{p}_{ij}}{\hat{p}_i}\right|$$

Where

$f_{ij} = \begin{bmatrix} f_{11} & \cdots & f_{1m} \\ \vdots & \ddots & \vdots \\ f_{m1} & \cdots & f_{mm} \end{bmatrix}$ **is the frequency for n months with which an Xn process progresses one step from state i to state j so that if $\chi^2 > \chi^2_{(\alpha,(m-1)^2)}$**

the process can be considered to have Markov properties. Where k= $\sum_{m=1}^{k} m$ is the total number of steps from 1 to k. the one-step transition probability can be expressed as Equation

$$p_{ij} = \mathrm{P\{X_{n+1} = x_j \setminus X_n = x_i\}},$$

$$p = \begin{bmatrix} p_{1,1} & \cdots & p_{1,j} & \cdots & p_{1,m} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ p_{i,1} & \cdots & p_{i,j} & \cdots & p_{i,m} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ p_{m,1} & \cdots & p_{m,j} & \cdots & p_{m,m} \end{bmatrix}$$

were

1. **The row element indicates the probability that it will be transported to the column element's position**
2. **The column element denotes the possible next location of the moving object.**

The k-step transition probability can be expressed as Equation

$$p_{ij}{}^{(k)} = \mathrm{P\{X_k = x_j \setminus X_0 = x_i\}},$$

$$p^{(k)} = \begin{bmatrix} p_{1,1}{}^{(k)} & \cdots & p_{1,j}{}^{(k)} & \cdots & p_{1,m}{}^{(k)} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ p_{i,1}{}^{(k)} & \cdots & p_{i,j}{}^{(k)} & \cdots & p_{i,m}{}^{(k)} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ p_{m,1}{}^{(k)} & \cdots & p_{m,j}{}^{(k)} & \cdots & p_{m,m}{}^{(k)} \end{bmatrix}$$

3. Weighted Markov Chain (WMC)

The weight of the starting state in the Markov chain is not simply 0 or 1, but each state in the weighted Markov is examined according to a fair calculation, so the formula and weight are calculated again.in the weighted Markov chain, the weight (w) will be carried out for each previous time k, k ∈ {1,2, …, m}. The probability that a process will be in a state at some point in the future is determined by the states it was in previously till k. When facing the Covid-19 pandemic, this weight is useful to describe the portion of each k in predicting CPI. If r_k is the k order autocorrelation coefficient of the data values $\{x_n\}$,n is the length of the reference sample sequence ,x_t is the value of the t time ; $\overline{x}$ is the data mean ,maximum order of prediction inquiry which can be formed as (Zhihang et al. 2010) .

$$r_k = \frac{\sum_{t=1}^{n-k}(x_t-\overline{x})(x_{t+k}-\overline{x})}{\sum_{t=1}^{n}(x_t-\overline{x})^2}$$

Any weight for each k can be formed as $w_k = \frac{|r_k|}{\sum_{k=1}^{m}|r_k|}$

once we acquire the Markov chain weights, future consumer price index can be done as formula

$$\widehat{p}_{ij} = \sum_{k=1}^{m} w_k\ (\widehat{p}_{ij})^k, \qquad \text{for } j \in \{1,2, \dots , m\}$$

is the probability that the consumer price index can be in state j in the future.

The total of the chain may be used to calculate the autocorrelation coefficient of various stages because the weighted Markov chain is weighting autocorrelation coefficient of various steps. have more sufficient and reasonable forecasting in using data

4. Application

This study examines the Egyptian consumer price index, which fluctuates in value in an unpredictable manner, and attempts to solve the problem using the weighted Markov chain method. The model utilized was a first-order Markov model, which means that the next position is decided solely by the current location and has no bearing on all previous states. As a result, the state of the future at any one time is simply tied to the current condition. in this method, the standardized self-coefficients are assumed to be weights based on the unique qualities of the consumer price index. The data source used in this study is https://www.capmas.gov.eg/Pages/IndicatorsPage.aspx?Ind_id=5696

The Egyptian consumer price index (CPI) from (feb-2020) to (jul-2021). – Prices of 2018/2019 are used as base period for the new CPI series. We can define the variables as X = consumer price index= (CPI), $\bar{x}$= CPI average, S = CPI standard deviation, m = number of states, n = lots of data, k = number of cases. we assume that any single class of (CPI) in time series depends on its previous class. R-statistical programming package version 4.2.1 was used for the analysis of WMC, the algorithm for the weighted Markov chain can be found here (WMC): (Qing-xin Z. (2015))

1. **Calculate the standard deviation s and the mean value $\bar{x}$ of historical data. The mean value $\bar{x} = 109.5667$ and standard deviation s= 2.6406**
2. **Classify historical data into m states. Since, monthly Egyptian consumer price index (CPI) classifications are assumed to follow first order Markov chain. by aligning the role of the mean and standard deviation to determine the weights for WMC model is provided as shown in Table 1.**

Table 1: Classify (CPI) data into m states

	date	cpi	State	f_{ij}	f
1	Feb 2020	105.2	1		
2	Mar2020	105.8	1	11	1
3	Apr2020	107.5	2	12	1
4	May2020	107.7	2	22	5
5	Jun2020	107.5	2	22	
6	Jul2020	107.8	2	22	
7	Aug2020	107.4	2	22	
8	Sep2020	107.5	2	22	
9	Oct2020	109.9	3	23	1
10	Nov 2020	111.2	3	33	6
11	Dec2020	110.6	3	33	
12	Jan2021	110.2	3	33	
13	Feb2021	110.3	3	33	
14	Mar2021	110.9	3	33	
15	Apr2021	112.2	3	33	
16	May2021	112.9	4	34	1
17	Jun2021	113.2	4	44	2
18	Jul2021	114.4	4	44	

According to the relationship between consumer price index and inflation rate, the national consumer price index from (feb 2020) to (jul 2021) is divided into four state spaces, namely low-inflation, med-inflation, high inflation and serious inflation, as shown in Table 2.

Table 2: (CPI) classification criteria

cluster	Interval	classification	classification mean
1	X$< \bar{x}-\sigma$	X< 106.9	low-inflation
2	$\bar{x}-\sigma \le$X$< \bar{x}$	$106.9 \le$X< 109.3	med -inflation
3	$\bar{x} \le$ X$< \bar{x}+\sigma$	$109.6 \le$ X< 112.2	high -inflation
4	$\bar{x}+\sigma \le$ X$\le \bar{x}+3\sigma$	$112.2 \le$ X≤ 117.5	serious -inflation

4. **classification (CPI) states and transition probability matrix:**

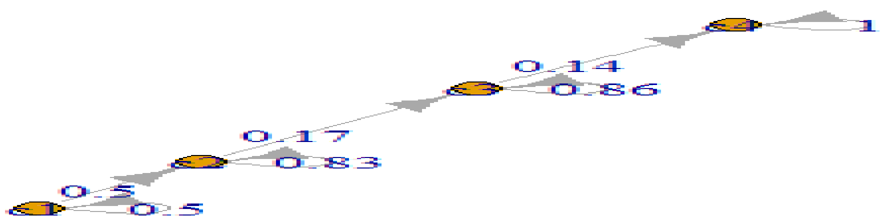
Create the frequency matrix F = (f_{ij}), The number $f_{i\,j}$ denotes the number of times the stochastic process xi moves one step from state i to state j.Let X_k be the time series of (CPI) classes, where X_k may assume the (CPI) classes c_1, c_2, c_3, and c_4 depending on the classification criteria of (CPI) index. The following transition probability matrix can be used to illustrate the transient behavior of each (CPI) class. way

$$F=\begin{bmatrix} 1 & 1 & 0 & 0 \\ 0 & 5 & 1 & 0 \\ 0 & 0 & 6 & 1 \\ 0 & 0 & 0 & 2 \end{bmatrix}, P=\begin{bmatrix} 0.5 & .5 & 0 & 0 \\ 0 & 0.8333 & 0.1667 & 0 \\ 0 & 0 & 0.8571 & 0.1429 \\ 0 & 0 & 0 & 1 \end{bmatrix},$$

$$q=\begin{bmatrix} 0.1111 \\ 0.3333 \\ 0.3889 \\ 0.1111 \end{bmatrix}$$

Here, note that

1. **f_{13} = 3 is the value in row 1 column 3 of F. it means that from state 1 to state 3, there are three one-step transitions.**
2. **p_{21} =0.8333, in row 2 column 1Form the one-step transition matrix P = (p_{ij}) means that the one-step transition probabilities from state 2 to state 1 equals 0.8333**
3. **and q_{21} = 0.3333 in row 2 column 1 of the marginal matrix q = (q_i), means that the probability of a stochastic process is on the state 1 equals 0.3333. We can also plot p as shown in figure 1 (Pyae, 2019).**
   figure 1: the probability of a stochastic process



Using the Chi-Square test, determine whether a stochastic process {χ^2}possesses the Markov property. the estimated $\chi^2 = 4$ with degree of freedom=9, And corresponding p-value is: 0.9954, We do not rule out the null hypothesis that the sequence

follows the Markov property because the p-value is greater than 0.05., so the annual (CPI) conformed to the 'Markov property; therefore, WMC prediction theory can be applied.

5. **Check the Markov absorbing state shows that state 4 is absorbing state, so the matrix (p) is Absorbing Markov chains. it has specific unique properties that for (m) transients and k absorption states, the transfer matrix P can be written in the canonical form as (Abdul Fatah et al 2012)**
$$p = \begin{bmatrix} Q & R \\ 0 & Ik \end{bmatrix}$$

Q = m ×m matrix of the probability of transitioning between temporary states, and R = m × k transition probabilities matrix from transitory states to absorbing states, Ik = k × k identity matrix, Where m × m matrix of transition.

$Q = \begin{matrix} 0.5 & 0.5 & 0 \\ 0 & 0.8333 & 0.1667 \\ 0 & 0 & 0.8571 \end{matrix}$	$R = \begin{matrix} 0 \\ 0 \\ 0.1429 \end{matrix}$
$0 = 0 \quad 0 \quad 0$	$Ik = 1$

By decomposing the transfer matrix into a basic matrix (Arias, (2018))

$$\text{N} = (\text{It} - \text{Q})^{-1} = \begin{bmatrix} 2 & 5.9988 & 6.9979 \\ 0 & 5.9988 & 6.9979 \\ 0 & 0 & 6.9979 \end{bmatrix}$$

n_{ij} of N gives the expected number of times that the process is in the transient state S_j if it is started in the transient state S_i we can calculate:

a) **The number of expected steps until it is absorbed from each state.**
b) **The chance of being absorbed by a certain absorbing state (state when starting from any given temporary state). The following formula is used to compute this probability**
c) $\textbf{Probabilities of absorption} = \textbf{N} \times \textbf{R} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix}$

d)$p^n = \begin{bmatrix} Q^n & R\sum_{i=0}^{n-1} Q^i \\ 0 & Ik \end{bmatrix}$**, So**

$$p^2 = \begin{bmatrix} Q^2 & R + QR \\ 0 & Ik \end{bmatrix}, p^3 = \begin{bmatrix} Q^3 & R + QR + Q^2R \\ 0 & Ik \end{bmatrix},$$

$$p^4 = \begin{bmatrix} Q^4 & R + QR + Q^2R + Q^3R \\ 0 & Ik \end{bmatrix}$$ (Allan (2021).)

Table (3) shows Markov chain ($p^{(1)}, p^{(2)}, p^{(3)}, p^{(4)}$) calculations

Table (3) Markov chain ($p^{(1)}, p^{(2)}, p^{(3)}, p^{(4)}$)

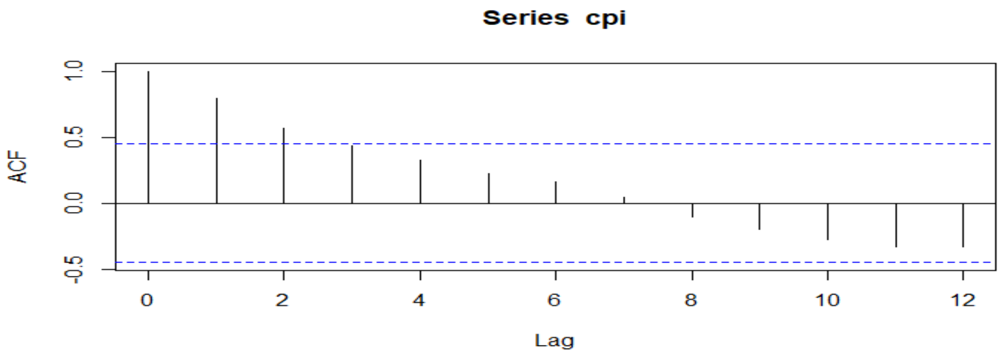
$Q=\begin{bmatrix} 0.5 & 0.5 & 0 \\ 0 & 0.8333 & 0.1667 \\ 0 & 0 & 0.857 \end{bmatrix}$	$p^{(1)}=\begin{bmatrix} 0.5 & 0.5 & 0 & 0 \\ 0 & 0.8333 & 0.1667 & 0 \\ 0 & 0 & 0.857 & 0.1429 \\ 0 & 0 & 0 & 1 \end{bmatrix}$
$Q^2=\begin{bmatrix} 0.25 & 0.25 & 0 \\ 0 & 0.6943 & 0.0277 \\ 0 & 0 & 0.7346 \end{bmatrix}$	$p^{(2)}=\begin{bmatrix} 0.25 & 0.25 & 0 & 0 \\ 0 & 0.6943 & 0.0277 & 0.0238 \\ 0 & 0 & 0.7346 & 0.2653 \\ 0 & 0 & 0 & 1 \end{bmatrix}$
$Q^3=\begin{bmatrix} 0.125 & 0.125 & 0 \\ 0 & 0.4822 & 0.0046 \\ 0 & 0 & 0.6296 \end{bmatrix}$	$p^{(3)}=\begin{bmatrix} 0.125 & 0.125 & 0 & 0 \\ 0 & 0.4822 & 0.0046 & 0.0278 \\ 0 & 0 & 0.6296 & 0.3704 \\ 0 & 0 & 0 & 1 \end{bmatrix}$
$Q^4=\begin{bmatrix} 0.0625 & 0.0625 & 0 \\ 0 & 0.4821 & 0.0008 \\ 0 & 0 & 0.5396 \end{bmatrix}$	$p^{(4)}=\begin{bmatrix} 0.0625 & 0.0625 & 0 & 0 \\ 0 & 0.4821 & 0.0008 & 0.0284 \\ 0 & 0 & 0.5396 & 0.4603 \\ 0 & 0 & 0 & 1 \end{bmatrix}$

6. **All-order autocorrelation coefficients are calculated using (R 4.1.2) software as**

Table (4) Markov chain ACF of (CPI)

K	0	1	2	3	4	5	6
ACF	1.000	0.755	0.529	0.389	0.281	0.215	0.161
K	7	8	9	10	11	12	
ACF	0.030	-0.154	-0.289	-0.338	-0.312	-0.303	

(CPI) self-correlation coefficients



From autocorrelation test, it can be judged that

a. **Autocorrelation coefficient within a short delay is always positive and then negative all along.**
b. **Autocorrelation distribution is not of triangular symmetric, indicating that distribution features of (CPI) up to basic assumption of the amended weighted Markov chain model**

7. **The self-correlation coefficients and Markov chain weights of (CPI) can be estimated using the Table 1 as indicated in Table (5)**

Table (5): Each Order Autocorrelation Coefficient and the Weight of each Step

k	1	2	3	4
r_k	0.755	0.529	0.389	0.281
w_k	0.3863	0.2707	0.1991	0.1438

8. **For Aug 2021(CPI), the consumer price index can be predicted in the future using the Markov chain weights and the corresponding transition probability matrixes according to the states. The resulting prediction is a state, namely c4 at $(112.2 \leq X \leq 117.5)$. From the foregoing, with monthly price index data of the last four months (from Apr 2021 to Jul 2021) of Egyptian price Index as initial data, in future two months of Egyptian price Index. we can also predict state probabilities, and see the calculation results in Table (6).**

Table (6) predict state probabilities, For Aug 2021(CPI)

initial	State	step		Weight	state 1	2	3	4
2021 Apr	3	4	$p^{(4)}$	0.3863	0	0	0.539	0.4604
2021May	4	3	$p^{(3)}$	0.2707	0	0	0	1
2021 Jun	4	2	$p^{(2)}$	0.1991	0	0	0	1
2021 Jul	4	1	$p^{(1)}$	0.1438	0	0	0	1
					0	0	0.208	0.7915

The result in table (6) showed that max $(p_{ij}, j = 1, 2, \dots, m)$= 0.7915, indicating that (CPI) was in cluster 4, which met the block interval of $(112.2 \leq X \leq 117.5)$ with a probability of 0.7915. The obtained predict (CPI)= 114.85%, still falls in the state 4.

For Sep 2021(CPI) prediction as shown at Table (7) with a probability of 0.7976. the obtained predict (CPI)= 116.785%, still falls in the state 4.

Table (7) predict state probabilities, For Sep 2021(CPI)

initial	State	step		Weight	state 1	2	3	4
2021May	3	4	$p^{(4)}$	0.374	0	0	0.5396	0.4604
2021 Jun	4	3	$p^{(3)}$	0.2660	0	0	0	1
2021 Jul	4	2	$p^{(2)}$	0.2062	0	0	0	1
2021Aug	4	1	$p^{(1)}$	0.1530	0	0	0	1
					0	0	0.2018	0.7976

from the historical data, we get the actual (CPI) and the Predict (CPI)was calculated as showed before we get table (8)

Table (8) the actual (CPI) and predict (CPI)

month	actual (CPI)	Predict (CPI)	chance
Aug2021	114.3	114.85	79.15%
Sep2021	116.1	116.785	79.76%

9. To measure the error of method, the Mean Absolute Percentage Error (MAPE) is calculated as follows (Obasohan (2020))

$$MABE = \frac{1}{n}\sum_{r=1}^{n}\left|\frac{X_t - X^*_t}{X_t}\right| * 100 = \frac{1}{N}\sum_{r=1}^{n}\left|\frac{\text{actual} - \text{Predict}}{\text{actual}}\right| * 100 = 0.53556$$

For the current model, the MAPE value is 0.5356, It’s indicated that the average absolute difference between original value and the predicted value is 53.56% where at time t, X_t is the actual (CPI), and X^*_t is the forecasted (CPI).

5. conclusion

As a conclusion, we can find that: of short-term trend of Egyptian consumer price index, the weighted Markov chain can effectively probabilities and forecast fluctuation ranges. Based on the results of the study, The research period reveals that the value of (CPI)Index in the 18th and 19th month are 114.85% has a 79.15% chance (in the 18th) , and116.785% has a 79.76% chance (in the 19th). It is satisfactory results. When facing the Covid-19 pandemic, The Egyptian (CPI) prediction results show that the serious -inflation in Egyptian economic will increase in the future. To analyze future economic developments, To aid the government or relevant agencies, a weighted Markov chain application approach can be devised.

References

1. **Abdul Fatah S. M., Abdul Hamid M. R, and Ahmed M. K., (2012). Decision Support System Based Markov Model for Performance Evaluation of Students Flow in Computers Faculties (Case Study: King Abdulaziz University). Journal of King Abdulaziz University, Vol. 1,pp104-105.**
2. **Allan Y. (2021). Absorbing Markov Chains. https://www.math.umd.edu/~immortal/MATH401/book/ch_absorbing_markov_chains.pdf, p. 5.**
3. **Arias, F. J. (2018). Markov Chain Analysis in R. Tutorials.**
4. **El-Sheikh A.A. k. S. (2013). Time Series Analysis of Inflation in Egypt. 48th The Annual Conference on Statistics, Computer Science and Operation Research.**
5. **https://www.capmas.gov.eg/Pages/IndicatorsPage.aspx?Ind_id=5696.**
6. **Indah, P.S. S., Rina W., and Nurul H. P. (2021). A Weighted Markov Chain Application to Predict Consumer Price Index When Facing Pandemic Covid-19. Journal of innovation and technology in mathematics and mathematics education. Vol. 1, No. 1, pp. 41-46**
7. **Kafi, R.A., Safitri Y.R., WidyaningsihY. and Handari B.D. (2019) .AIP Conference Proceedings. https://doi.org/10.1063/1.5132460**
8. **Martina, A. (2021) . Multivariate Markov Chain Model for Sales Demand Estimation in a Company. International journal on information and communication technology, vol. 7 pp. 48-57**
9. **Obasohan, P. E. (2020). Comparing Weighted Markov Chain and Auto-Regressive Integrated Moving Average in the Prediction of Under-5 Mortality Annual Closing Rates in Nigeria. International Journal of Statistics and Probability; Vol. 9, No. 3;p13.**
10. **Pyae, A. (2019). Operations Research and Optimisation Booth setting project. https://www.researchgate.net/publication/333104842_Operations_Research_and_Optimisation_sample_project_-_Setting_a_booth.**

11. **Qianhong, S. (2020). Application of Markov Chain to the Prediction of Consumer Price Index. Scholars Journal of Physics, Mathematics and Statistics. vol.7,pp. 93-95).**
12. **Qing-xin Z. (2015). Application of Weighted Markov Chain in Stock Price Forecasting. Advanced Science and Technology Letters. Vol.8, No.2, pp.219-226.**
13. **Sun, Y. (2020). Index Forecast Study Based on Amended Weighted Markov Chain in China. International Journal of Trade, Economics and Finance. Vol. 11, p 98.**
14. **Zhihang , P. ,Changjun , B., Yang, Z., Honggang , Y., Letian , X., Hao , Y., . . Hongbing , S., and Feng C ., (2010). Weighted Markov chains for forecasting and analysis in Incidence of infectious diseases in jiangsu Province, China. Journal of Biomedical Research, Vol. 24: , pp.207-214.**
15. **Zulfiqar A., Ijaz H., Muhammad F, Ibrahim M. A., Muhammad I., Maqsood A., and Ishfaq A.,(2018). A New Weighting Scheme in Weighted Markov Model for Predicting the Probability of Drought Episodes. Advances in Meteorology, Volume 2018. p 10.**