Wheat Procurement Forecasting for Indian PDS Using Regression Model

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Abstract— In this paper the regression model is developed to forecast the wheat procurement for PDS in India. The FCI(Food Corporation of India) procure various food grain to ensure food security to all Indians. Indian PDS(Public Distribution System) is one of the largest supply chain which covers more than 800 million beneficiaries and have FPS(Fair price Shops) across the country. In this paper we computed the errors and Theil's U coefficient for the proposed method to show its efficacy and the results turned out to be acceptable.

Keywords: Forecasting, Food Supply chain, Indian PDS , Regression,Theil's U coefficients.

I. INTRODUCTION

Food corporation of India procure wheat and other grain from farmers for distribution and for ensuring food security. The wheat procurement happens in the rabi market season (RMS). Indian PDS is one of the largest supply chains which covers more than eighty crore beneficiaries directly and covers whole India. This supply chain attained a steady state. The aggregate demand and production and changes in these are less than ten percentage in the last ten years. In this research procurement data for last ten years and grain movement both interstate and intra state are taken from FCI database. FCI has 21,106 procurement centers for wheat procurement during Rabi Market Season (RMS) and 74684 procurement centers for paddy procurement during Kharif Market Season (KMS). There are 537,230 fair price shops (FPS) spread across India, through which the distribution of this procured grain to public happens. The district wise aggregate demand is known.

II. INDIAN PDS SUPPLY CHAIN
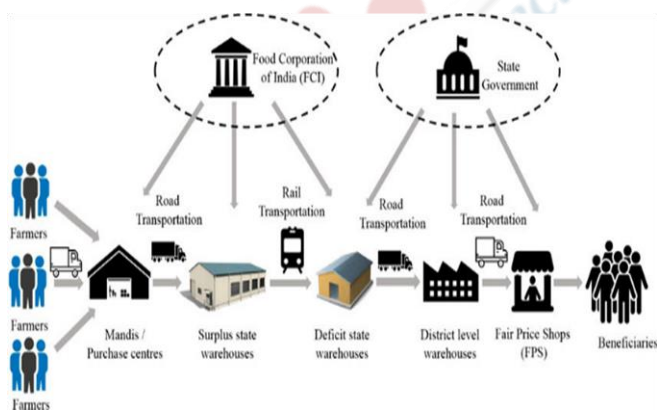
Fig 1. Stages in Flow of Grain from procurement to Distribution

The Fig1 by Singh S.K etal [1] explains how the grain movement happens from central ware house to state warehouse and to district level ware house for distribution. There are 735 districts the transportation of grain happens using rail and road. The grain procured by FCI falls under restriction of WTO, means FCI can export grains only for welfare programs. FCI can release its stock in domestic market, if necessary, to control inflation and ensure food security.

The table [1] shows the procurement of wheat for the past ten years, unit is in LMT(Lakh Metric Ton). The past five years starting from 2017 India registered record wheat yield so the procurement also increased substantially.

Table 1. Wheat Procurement in LMT(Lakh Metric Ton) from states.

States	Punjab	Haryana	UP	M.P.	Rajasthan	India
RMS 2012-13	128.36	87.17	50.63	85.07	19.64	382.15
RMS 2013-14	108.95	58.55	6.83	63.55	12.69	250.72
RMS 2014-15	116.44	65.08	6.28	71.89	21.55	281.31
RMS 2015-16	103.44	67.78	22.67	73.09	13	280.88
RMS 2016-17	106.49	67.52	7.97	39.92	7.62	229.61
RMS 2017-18	117.06	74.32	36.99	67.25	12.45	308.24
RMS 2018-19	126.92	87.84	52.94	73.13	15.32	357.95
RMS 2019-20	129.12	93.2	37	67.25	14.11	341.32
RMS 2020-21	127.14	74	35.77	129.42	22.25	389.92
RMS 2021-22	132.22	84.93	56.41	128.16	23.4	433.44

Wheat procurement from the five states Punjab, Haryana, Uttar Pradesh, Madhya Pradesh and Rajasthan contribute more than 97%(Fig:3) of the total procurement. Uttar Pradesh and Rajasthan are self-sufficient states and no wheat movement happen out of these states. Procurement happens once in a year during Rabi crop season. The interstate wheat movement happen from Punjab, Haryana and Madhya Pradesh. In this study the procurement from this state and movement of grain from this state are considered as total procurement and movement. The grain movement happen from surplus state to deficit state and intra state movement happen for state consumption. The states Gujarat, Maharashtra, Orissa, Bihar and all southern states are deficit states and wheat movement happen from the surplus state like Punjab and Haryana and Madhya Pradesh.

All states have storage capacity to meet out one year demand and replenishment happen in monthly basis from the surplus state. Storage capacity with FCI are of three types 1. Open storage 2. Cover and Plinth (CAP)   3. Complete Storage (Warehouse, Silos etc.) the first two are for temporary storage the grain stored there gets priority for distribution or transportation. If FCI procure more than what can be stored it results in higher wastage and lesser utilization.
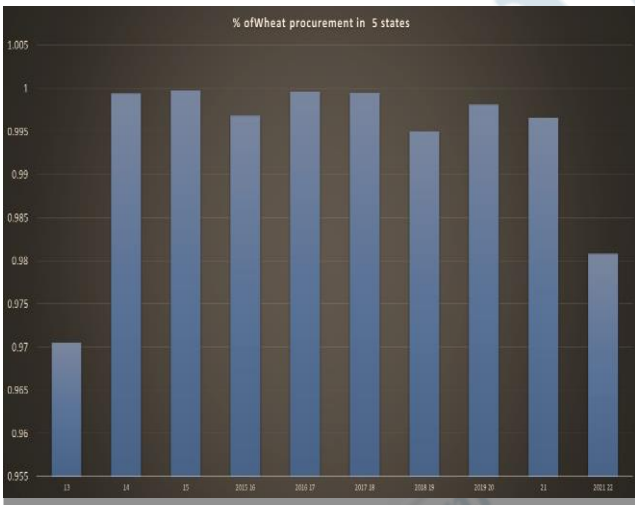

Fig 2: Procurement percentage of first 5 states.

III. REGRESSION MODEL

We took the total procurement and interstate movement and Punjab state procurement and interstate movement to show the effectiveness of this method. The change in inventory is calculated based on the formula

Change in Inventory = (Procured wheat)- (Wheat moved out of the state through Rail and road transport)- (intra state movement for consumption)

The Correlation coefficient between procurement and grain movement was calculated and it was positive.

Punjab	Procurement	Inventory Movement
Procurement	1	
Inventory movement	0.891412214	1

Total	Procurement	Inventory Movement
Procurement	1	
Inventory movement	0.941722326	1

The correlation coefficient was positive and the P value was less than 2% which justify the effectiveness of the correlation coefficient.

	Punjab	Total
	P-value	*P-value*
Intercept	9.01E-07	0.000149
X Variable 1	0.017047	0.004995

Using these data, a regression line which fit the data was developed for Punjab and total procurement for whole country. The R^2 value was .796 and .8868 respectively.
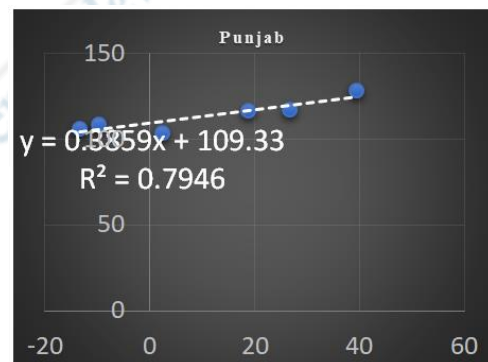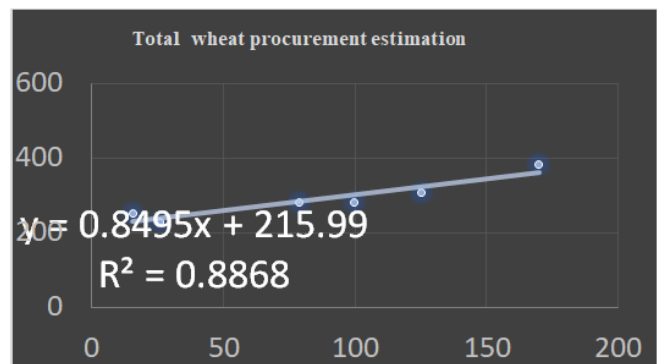

Fig 3: Regression model for Punjab procurement

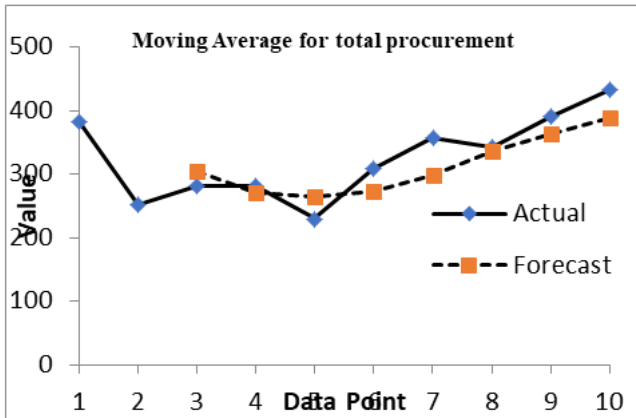**Fig 4.** Regression model for Total procurement

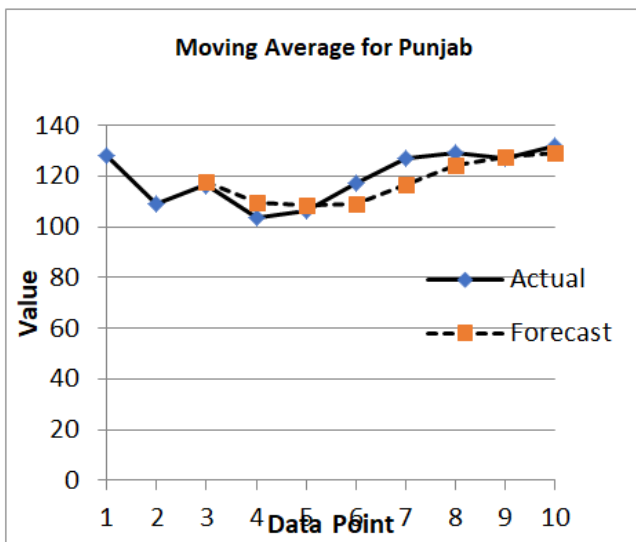**Fig 5.** Moving average model for total procurement

Fig 6 . Moving average plot for Punjab procurement

A). Error Comparison between different methods (unit LMT)

Using these data, the error analysis was done to test the accuracy of this method MAD (Mean Absolute Deviation), MSE (Mean Square Error), MAPE (Mean absolute Percentage error) were calculated using the formula and result were shown in table 3. The MAPE for the regression model was around 5%.

$$MAE = \frac{\sum_{t=1}^{n}|e_t|}{n}$$

$$MSE = \frac{\sum_{t=1}^{n}(e_t)^2}{n}$$

$$MAPE = \frac{\sum_{t=1}^{n}\left|\left(\frac{D_t - F_t}{D_t}\right)*100\right|}{n}$$

Where e_t is difference between actual demand and forecasted demand for period t

D_t actual demand for period t

F_t forecasted demand for period t

	Errors	Simple Avg	Moving Avg	Regression Mode;
Total	MAD	-3.126E-14	34.41	0.0051
	MSE	3934.1997	1231.55	267.14
	MAPE	17.87607587	9.2210979	5.013786
Punjab	MAD	-2.842E-15	5.844	-0.002
	MSE	99.994184	37.27	14.143
	MAPE	7.804165361	3.805143	2.860566

Table3. Error Comparison.

B). Theil's Coefficient:

Theil's U value says about the proposed method by comparing it to the naïve method. In naïve method the forecast value is the previous period's actual value. The coefficient greater than one implies the proposed method is worse than naïve method, equal to one implies the proposed method is as good as the naïve method, lesser than one implies the proposed method is better than naïve method. The value very close to zero the better the method.

Theil's _U_ determins the forecasting performance of the model. Interpret Theil's U greater than one implies the proposed model is worse than naïve method, equal to one implies the proposed model is as good as naïve method, lesser than one implies the proposed model is better than naïve method Theil's _U as follows:_

1.00 – 0.80 Very weak forecasting power
0.80 – 0.60 Weak forecasting power
0.60 – 0.40 Moderate forecasting power
0.40 – 0.20 Moderately high forecasting power
0.20 – 0.00 High (strong) forecasting power

$$U = \sqrt{\frac{\sum_{t=1}^{n-1}\left(\frac{F_{t+1} - D_{t+1}}{D_t}\right)^2}{\sum_{t=1}^{n-1}\left(\frac{D_{t+1} - D_t}{D_t}\right)^2}}$$

Where,

F_{t+1} forecasted value for period t+!

D_{t+1} actual demand value for period t+1

D_t actual demand for period t

Thiel's U is calculated using the given formula and values are, by this value it can be concluded that the correlation method is better than naïve's method.

	Punjab	Total
Theil's U	0.320739	0.211788

Table 4. Theil's U Coefficient

IV. CONCLUSION

A In the proposed method the correlation between the Wheat movement and Procurement quantity was found and the P value is below 2% and causation is justified. Compare to the other method like moving average and simple average the forecasting error is lesser in this approach. The MAPE also lesser than 5%. The Thiel's U value are also lesser than .4 implies the method is moderately high forecasting power. The procurement can be done based on this approach to limit the wastage and improve the utility.

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