Forecasting Wheat Production in Punjab: An Appraisal

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It is generally believed that Pakistan is not self-sufficient in wheat. Each year the government plans for wheat imports to fill the estimated shortage of wheat. Effective import policy can only be formulated on the basis of sound forecasting of the related variables. This note has a limited purposes of reviewing the existing forecasting techniques for wheat production. The broad conclusion that emerges from the review indicates a possibility of con- siderable scope for improvement in the current forecasting techniques.

I. The Existing Forecasting Models

The Ministry of Food and Agriculture maintains a crop estimates calendar according to which three successive estimates are issued for wheat.[1] The first estimate for wheat crop is released on February 1 each year. This estimate pertains only to area sown. The estimate is based on the reports of Deputy Commissioners compiled from *tehsil returns* submitted by revenue officials. The Department of Agriculture, Government of Punjab, modifies the estimates submitted by district officials in the light of reports received from officers of its own department. The second estimate for wheat is released on April 1 each year. This estimate revises the earlier estimate for wheat area and shows an estimate for wheat production. The area estimates are based on reports from local officials of revenue department and of department of agriculture. The yield per acre is based on subjective estimates by the revenue and agriculture staff in the field. The yield estimates for different districts are reconciled by the Agricultrual Statistical Cell, Department of Agriculture at Lahore to arrive at the provincial figures for yield per acre. This reconciliation is based on data on historical yield level, rainfall, canal discharges and the use of various inputs for the wheat crop. The third and final estimate for wheat is released on August 1 each year. The area estimates are taken from the *mouza Jinswars* and are tabulated with the help of an electronic computer. The official yield estimates are

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[1]For details on the institutional structure and an evaluation of the quality of data, see [5].

fixed in the light of the results of the objective crop cutting experiments carried out by the Department of Agriculture. It is generally believed that the acreage data are quite reliable while the production data warrants improvements in its quality. The differences between wheat production as estimated in April and actual production figures as estimated in August are too large[2] to justify their use in any serious way by policy-makers.

Azhar, *et al* [1] has developed an econometric model specifically for forecasting wheat production in the Punjab province of Pakistan. Chaudhry and Kemal [2] have modified the Azhar model by redefining the rainfall variable. Both models are based on technical relationships and economic theory of causal processes. Wheat production (y) is postulated to be a function of the area under Mexi-Pak variety (X_1), the area under local variety (X_2), the nutrient tons of fertilizer applied to total wheat acreage (X_3) and rainfall during the months of November, December and January (X_4). In the case of Chaudhry-Kemal model, rainfall (X_4) is defined as deviations of actual rainfall from normal rainfall during seven months of July to January for the wheat season. The parameters in the two models are the ordinary least squares estimates for 1967-68 to 1971-72. Regression equations are estimted by pooling data across districts for five years. Conceptually the potential accuracy of a forecasting procedure would be positively related to the degree to which the specified model approximates the true and unknown causal processes generating the forecast variables. It is possible that structural models may not be accurate in predictions if specification errors are not avoided and/or the structure on which the model rests experiences a change over time.

To evaluate the Azhar and Chaudhry-Kemal models (henceforth referred to as sophisticated models) a time series model referred to as a naive model had been estimated. Time series model forecasts[3] relate the future value of series to its own past values. These forecasts have little to do with economic theory. These models are simple, easy to apply and often quite accurate in predictions. These models require much less information than the structural models and can be useful in evaluating the forecasting performance of the formal models.

The time series model used in the present study is quite simple. It is assumed that the yield per acre of each of the two varieties of wheat in year t equals the observed average yield for the given variety over the previous four years. Wheat production is obtained by multiplying sown acreage and the estimated yield per acre for each variety and summing the production for the two varieties of wheat.

II. An Evaluation of Wheat Forecasts

Various criteria have been proposed for comparing and evaluating the different forecasting models. The extent to which the forecasts foretell the future with minimum errors is the basic consideration in such an evaluation. Loss functions of the users of forecasts need to be known to discriminate between different forecasting devices. Most often loss functions are not known, however. A number of test statistics have been developed and are useful in the

[2]For evidence on this aspect, see [5].

[3]For a discussion of different types of time series model, see [3].

Table 1

Evaluation of Sophisticated and Naive Model Forecasts of Wheat for Districts and Punjab Province (By Non-Irrigated and Irrigated Zones)

Non-Irrigated, Irrigated Districts and Zones, the Punjab	Average Annual Level of Production 1971-72 to 1974-75 (Thousand Tons)	Azhar Model[1]		
		Mean Absolute error[2] (Thousand Tons)	Mean Percent error[3]	Ratio of Turn-Point errors[4]
Non-Irrigated				
Campbellpur	107.85	15.58	14.06	0:4
Rawalpindi	60.00	11.90	19.19	2:4
Jhelum	65.60	12.69	16.10	1:3
Mianwali	182.03	15.04	8.35	0:2
Non-Irrigated Zone	415.48	101.15	25.31	1:4
Irrigated				
Gujrat	161.10	61.27	40.28	1:4
Sargodha	388.43	28.92	7.81	3:4
Lyallpur	639.13	61.36	10.18	0:4
Jhang	318.10	24.38	7.75	1:2
Sialkot	218.90	54.39	22.89	1:2
Gujranwala	311.30	32.59	11.81	0:3
Shiekhupura	275.50	61.52	24.11	1:4
Lahore	255.30	43.53	18.15	0:4
Sahiwal	682.95	54.93	8.33	0:4
Multan	812.40	104.79	12.56	3:3
Muzaffargarh	390.85	45.05	12.26	5:5
Dera Ghazi Khan	157.13	37.38	24.42	2:3
Bahawalpur	143.08	20.43	15.76	1:2
Bahawalnagar	174.50	25.34	14.76	2:4
Rahim Yar Khan	194.60	35.87	15.05	2:2
Irrigated Zone	5104.65	1850.93	37.45	1:4
The Punjab	5520.13	1954.11	36.48	0:4

—Continued

Table 1—(*Continued*)

Non-Irrigated, Irrigated Districts and Zones, the Punjab	Chaudhry-Kemal Model[5]			Naive Model[6]		
	Mean Absolute error[2] (Thousand Tons)	Mean Percent error[3]	Ratio of Turning Point errors[4]	Mean Absolute error[2] (Thousand Tons)	Mean Percent error[3]	Ratio of Turning Point errors[4]
Non-Irrigated						
Cambellpnr	26.88	24.02	2:4	23.02	19.51	3:4
Rawalpindi	12.90	21.14	4:4	10.37	16.47	3:4
Jhelum	11.18	17.70	3:3	10.18	14.64	4:3
Mianwali	18.33	9.93	0:2	31.01	18.23	2:2
Non-Irrigated Zon	73.13	18.52	1:4	60.47	13.83	4:4
Irrigated						
Gujrat	80.92	44.97	3:4	18.06	10.95	4:4
Sargodha	28.68	7.64	3:4	47.99	12.23	0:4
Lyallpur	71.96	11.85	0:4	71.20	10.68	2:4
Jhang	41.52	13.71	1:2	36.99	12.38	2:2
Sialkot	75.15	32.54	1:2	37.19	16.42	3:2
Gujranwala	41.16	15.00	2:3	38.42	14.50	1:3
Shiekhupura	47.01	21.43	1:4	42.00	17.28	3:4
Lahore	55.45	23.41	0:4	33.16	14.20	4:4
Sahiwal	55.27	8.34	0:4	66.31	10.35	2:4
Multan	116.93	14.70	3:3	95.45	11.74	4:3
Muzaffargrh	37.34	10.12	3:5	53.33	14.64	4:5
Dera Ghazi Knan	46.01	30.80	3:3	20.91	14.20	3:3
Bahawalpur	36.16	24.79	1:2	22.05	14.72	3:2
Bahawalnagar	25.00	14.64	2:4	12.48	8.49	4:4
Rahim Yar Khan	28.28	13.93	1:2	27.92	16.18	3:2
Irrigated Zone	1930.89	39.02	0:4	522.47	10.72	3:4
The Punjab	2004.20	37.37	0:4	567.32	10.66	2:4

—*Continued*

Table 1—*Continued*

[1]Forecst Mode [1 page 413]

(*a*) Irrigated Districts $\hat{y} = -113.59+0.55X_1+0.64X_2+0.02X_3-6.34X_4$

(*b*) Non-Irrigated Districts $\hat{y} = -43.79+0.46X_1+0.21X_2+0.03X_3+3.79X_4$

[2]Measured $\Sigma \mid \hat{y}_t - y_t \mid /8$

[3]Measured $\Sigma \left| \left\{ \left(\hat{y}_t - y_t\right) / y_t \right\} 100 \right| 8$

[4]Measured as number of turning point errors: number of turning points.

[5]Forecast Model [(2) Page 224]

(*a*) Irrigated Districts $\hat{y} = -115.37+0.58X_1+0.62X_2+0.02X_3+4.89X_4$

(*b*) Non-Irrigated Districts $\hat{y} = -14.48+0.44X_1+0.18X_2+0.03X_3+2.03X_4$

[6]Forecast Model: Yield per acre for each variety of Wheat in year t is assumed to equal the obsrved average yield for the previous four years. Wheat production for each variety is obtained by multiplying Wheat acreage under each variety by the estimated yield per acre.

evaluation of the different forecast models.[4] The mean forecast error (associated with a linear loss function), mean square forecast error (associated with a quadratic loss function), Theil's inequality statistic, and the number of time changes in the direction of the variable are correctly or incorrectly forecasted are some of the proposed test statistics.

Table 1 presents three test statistics for the Azhar model, Chaudhry-Kemal and the naive model. The mean absolute errors measures the average value by which the forecasts have over-estimated or under-estimated the actual value of wheat production. The mean percent error measures the average per cent by which the wheat forecasts have over-estimated or under-estimated the realized value of wheat production. The ratio of turning points criterion measures the number of times the wheat forecast falsely anticipates a direction of change relative to the actual number of directional changes in the series.

Some interesting results emerge from the table. The mean percent error for the Azhar, Chaudhry-Kemal and the naive models respectively ranges from 8 percent to 40 percent, 8 percent to 45 percent and 8 percent to 20 percent. The ranges for mean absolute error respectively for the three models are 12 to 1954 thousand tons, 11 to 2004 thousand tons and 10 to 567 thousand tons. It is clear that the navie model performs much better than the sophisticated models on the basis of the two criteria. In terms of forecasting changes in the direction of production, the false leads of changes in the direction respectively for the three models are 27, 34 and 63 when in fact there are 75 turning points for the sample of districts in Table 1. The naive model fairs much worse according to the ratio of turning points criterion.

The quadratic loss function of the users of forecasts would require that the mean squared errors of different models be taken into consideration in a criterion to evaluate the different forecasting models. The criterion developed for measuring the forecasting accuracy[5] of this kind is the ratio of the root mean squared error of the sophisticated model forecasts to the corresponding root mean squared error of the naive model forecasts. Denoting the sophisticated and naive model forecasts of wheat production by $\hat{Y}^1_t$ and $\hat{Y}^2_t$ respectively, the actual wheat production by Y^a_t and the number of forecast observations by n, the measure of forecasting accuracy (k) is as follows:

$$k = \frac{\left[1/n \sum_{t=i}^{n} (\hat{Y}^1_t - Y^a_t)^2 \right]^{1/2}}{\left[1/n \sum_{t=i}^{n} (\hat{Y}^2_t - Y^a_t)^2 \right]^{1/2}}$$

The interpretation of the values of k need some explanation. If the sophisticated model forecast are perfectly accurate, k would take the value of zero. If the sophisticated and the naive models predict wheat output with equal accuracy, the value of k would be unity. When the sophisticated model is more efficient than the naive model, values of k would be between zero and unity. Values of

[4]For a discussion of the different test statistics, see [3].
[5]For a use of this measure in another context, see [6].

k greater than unity would mean that the naive model is a better predictor relative to the sophisticated model.

Table 2 presents the values of k for Azhar and naive models, Chaudhry-Kemal and naive models and Azhar and Chaudhry-Kemal models. Taking the wheat forecasts for different districts, irrigated and non-irrigated zones and the Punjab province as a sample, we applied a nonparametric sign statistic to test for significant differences in the forecasting performance of different models. The results of the sign test reveal that wheat forecasts by Azhar model were neither significantly more or less accurate than naive forecasts. The wheat forecasts by the naive model are significantly more accurate than Chaudhry Kemal model and the forecasts by Azhar model are significantly more accurate than Chaudhry-Kemal model. The naive model is at least as good or better when compared with sophisticated models.

Table 2

Ratio of the Root Mean of Squared Errors of Sophisticated Model Forecasts to those Generated by the Naive Model: Time Series 1967-68 *to* 1974-75

Non-Irrigated, Irrigated Districts and Zones, the Punjab	Ratio: Azhar Model/Naive Model	Ratio: Chaudhry-Kemal Model/ Naive Model	Ratio Azhar Model/Chaudhry-Kemal Model
Non-Irrigated			
Campbellpur	0.64	1.22	0.49
Rawalpindi	1.07	1.08	0.99
Jhelum	1.14	1.08	1.05
Mianwali	0.60	0.75	0.80
Non-Irrigated Zone	1.42	1.10	1.44
Irrigated			
Gujrat	2.87	4.07	0.71
Sargodha	0.65	0.52	1.16
Lyallpur	0.84	0.94	0.90
Jhang	0.60	1.12	0.53
Sialkot	1.31	2.05	0.64
Gujranwala	1.00	1.15	0.87
Sheikhupura	1.83	1.11	1.64
Lahore	1.33	1.57	0.85
Sahiwal	0.86	0.92	0.93
Multan	1.12	1.23	0.91
Muzaffargarh	1.00	0.85	1.18
Dera Ghazi Khan	2.09	2.43	0.86
Bahawalpur	0.97	1.63	0.59
Bahawalnagar	1.41	1.63	0.87
Rahimyar Khan	1.16	0.96	1.20
Irrigated Zone	2.82	2.95	0.96
Punjab	2.69	2.77	0.97

Another obvious further question to ask is whether or not the sophisticated model forecasts have improved over time. It would be useful to know if they had. The experience of naive and structural macroeconomic models in other contexts indicates that the naive models perform at least as well or better from the viewpoints of squared error considerations in the short run but the structural models gain in accuracy with the passage of time [4]. Table 3 presents the values of Kendall T between time and the k-ratios for different models. A negative trend implies an improvement and a positive trend a deterioration in the forecasting performance of the sophisticated models.

Table 3

Kendall Rank Co-efficient of Correlation (T) between Time and Ratio of the Mean of Squared Errors of Different Models

Non-Irrigated, Irrigated Districts and Zones, the Punjab	*T*: Azhar Model/Naive Model	*T*: Chaudhry Kemal Model/ Naive Model	*T*: Azhar Model/Chaudhry Kemal Model
Non-Irrigated			
Campbellpur	0.61*	0.79*	—0.43
Rawalpindi	0.07	0.43	—0.39
Jhelum	0.07	0.36	—0.14
Mianwali	0.57*	0.47	0.07
Non-Irrigated Zone	0.36	0.36	—0.43
Irrigated			
Gujrat	—0.43	0.36	—0.11
Sargodha	0.43	0.57*	0.25
Lyallpur	0.36	0.50	0.29
Jhang	0.21	0.43	0.04
Sialkot	0.64*	0.15	0.39
Gujranwala	0.57*	0.54	—0.04
Sheikhupura	0.07	0.21	—0.21
Lahore	0.36	0.39	—0.57*
Sahiwal	0.55	0.46	—0.07
Multan	—0.21	0.11	—0.50
Muzaffargarh	0.47	0.50	0.14
Dera Ghazi Khan	0.54	0.54	0.21
Bahawalpur	0.43	0.21	—0.21
Bahawalnagar	0.29	0.54	0.15
Rahim Yar Khan	0.32	0.11	0.04
Irrigated Zone	0.50	0.50	—0.69*
Punjab	0.43	0.43	—0.57

*Significant at 5 percent level.

Comparing Azhar and the naive model, it is seen that only in two out of twenty-two cases the trends are negative indicating improvement over time of the forecasting accuracy of the Azhar model forecasts. The negative trends are not significantly different from zero, however. In three cases, the trends are significantly positive. In seventeen cases the trends are positive though not significantly different from zero. Comparing Chaudhry-Kemal and naive model, the naive model is seen to be improving its forecasting performances in all twenty-two cases though positive trend is significant only in two cases. Also Azhar model is getting increasingly better than the Chaudhry-Kemal model.

III. Concluding Remarks

Forecasts are needed to facilitate effective decision making. It is shown that the present forecasting methods for wheat production in Pakistan are subject to wide errors. It is generally believed that the formal models provide the most accurate forecasts. Our evaluation of these models shows that the potential gains in relative forecast accuracy have not been realized. This is most probably due to the fact that some important causal factors may not have been included in the analysis and/or errors of model specification and estimation may have been of sufficient magnitude to nullify the potential advantages of the formal models. The naive model, relative to the formal models, was a good predictor of wheat production. The absolute error from the naive model was quite large, however. Based on only the historical values of the forecast variable the naive model does not offer the opportunity of analysing the sources of forecast errors. There is need for improved formal models as they lend themselvesfor the analysis of forecast errors and revisions in the structural features of the model.

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