DEVELOPMENT OF A REGIONAL PROGRAMMING MODEL FOR SIMULATING THE SOUTH AFRICAN WHEAT INDUSTRY, WITH SPECIAL CONSIDERATION TO RISK

J Howcroft
MSc Agric. Student, Department of Agricultural Economics, University of Natal, Pietermaritzburg

GF Ortmann
Associate Professor, Department of Agricultural Economics, University of Natal, Pietermaritzburg

Abstract

Wheat is the second most important field crop grown in South Africa in terms of gross value. Most of the wheat produced is consumed in the form of bread which is one of the main staple foods in South Africa. Wheat is currently marketed under a one channel fixed price system. However in recent years there has been a trend to a more free market approach to the marketing of agricultural produce. Therefore the consequences of alternative marketing policies for wheat warrant investigation. For this purpose a regional mathematical programming model was developed with the objective of simulating the wheat industry. The model includes negative-sloping demand functions for various crops, substitution in demand between wheat and maize and risk in terms of variance-covariance matrices. It was found that average yield data could be misrepresentative when used in risk analysis. Therefore, where possible, a pooled data set was used. The results show that the model successfully simulates production in the main wheat growing regions of South Africa. This is shown by the estimated shadow price of land being similar to actual rents and by percentage absolute deviations of 12,2 per cent and 6,3 per cent between actual and predicted land use and production respectively. It is concluded that the model would be useful for policy research.

Samevatting

In terme van bruto waarde is koring die tweede belangrikste akkerbougewas wat in Suid-Afrika verbou word. Die meeste koring word verbruik in die vorm van brood wat een van die belangrikste stapelvoedsels in Suid-Afrika is. Koring word tans onder 'n eenkanaal-vasteprysskema bemark. Die afgelope paar jaar was daar egter 'n neiging na 'n meer vryemarkbenadering vir landbouprodukte. Dus is 'n ondersoek na die gevolge van alternatiewe bemarkingsbeleidsrigtings vir koring geregverdig. Vir hierdie doel is 'n wiskundige- programmeringsmodel op streeksbasis ontwikkel om die koringbedryf te simuleer. Die model behels vraagfunksies met negatiewe hellings vir verskeie gewasse, substitusie in die vraag tussen koring en mielies en risiko in terme van variansie-kovariansie-matrikse. Omdat gemiddelde opbrengstes individuele risiko uitkanseleer is daar gebruik gemaak van individuele data-basisse. Die resultate toon dat die model produksie in die belangrikste koringproduserende streke in Suid-Afrika suksesvol simuleer. Dit word aangetoon deur die skaduprys van grond wat soortgelyk is aan die werklike huur en deur die persentasie absolute afwykings van respektiewelik 12,2 per cent en 6,3 per cent tussen werklike en voorspelde grondgebruik en produksie. Daar word tot die gevolgtrekking gekom dat die model nuttig sou wees vir beleidsnavorsing.

1. Introduction

The economic importance of wheat production to South Africa can be summarised as follows : 1) Wheat contributes significantly to the total gross value of agricultural production; 2) wheat in the form of bread is one of the major staple foods in South Africa; 3) the domestic production of wheat results in the reduction of wheat imports which leads to savings on foreign exchange; 4) the wheat industry and its related secondary industries provide considerable employment.

Given the economic importance of wheat the future production and marketing of wheat need to be researched. At present wheat is marketed under a one-channel fixed-price system. To evaluate the consequences on domestic production of different marketing alternatives a linear programming (LP) model of wheat production at the regional level was developed. The model includes negative-sloping demand functions for crops, substitution in demand between wheat and maize, and variance-covariance matrices to account for income risk.

In the first part of the paper the development of the LP model is discussed, with the objective of simulating production in the South African wheat industry. Special consideration is given to risk with regards to the use of pooled data compared to average data in the variance-covariance matrix. This is followed by a discussion of the results of the simulation.

2. Development of the model

2.1 Demarcation of Homogeneous Areas

The main wheat producing regions of the country were divided into three regions, namely the Orange Free State/Transvaal (OFS/Tvl), Swartland and Rûens. These production regions were divided into reasonably homogeneous farming areas (RHFAs)

Scheepers *et al* (1984) divided the Highveld region into RHFAs. Use was made of the "Landbou-Ontwikkelingsprogram" of the Winter Rainfall Region (1985) which divides the Swartland and Rûens into RHFAs. No information on RHFAs for central Orange Free State was available and so magisterial district data were used for aggregation.

2.2 Alternative Crops

Crops that compete with wheat for land and other resources in the different production regions were identified and included in the model as production alternatives. In this way substitution in supply was included in the model. The area under the supply function of a crop also comprises the opportunity cost of producing that product (Nieuwoudt,1981).

In the OFS/Tvl region there are three main crops that compete with wheat for land, namely maize, sorghum and sunflowers. In the Swartland the competing crops are oats and pastures (for sheep and dairy herds). In the Rûens oats, barley and pastures for sheep are the main competing enterprises.

2.3 Cost Data

For cash crops, use was made of the General Farm Management Results, a publication by the Directorate of Agricultural Production Economics. These cost estimates relate to an entire production region. Owing to the lack of more detailed data, it was assumed that costs were constant over each production region. This assumption was partially relaxed in RHFAs where rainfall was considerably lower than the relevant production region. In these areas observed production costs were reduced as fertilizer was applied at significantly lower rates.

For the sheep and dairy enterprises, use was made of Combud reports compiled by the Directorate of Agricultural Production Economics.

2.4 Yields

Yields and stocking rates for the various RHFAs were obtained from Scheepers *et al* (1984) and the Landbou-Ontwikkelingsprogram (1985). For the magisterial districts in central Orange Free State yield data were taken from Agricultural census reports which is a publication by the Department of Statistics (1972).

2.5 Rotation of Crops

Account was taken of physical restraints on the production of crops in each production region. For example, sunflowers can only be grown once every three years (owing largely to disease and pest problems). Consequently the (annual) model allows only one-third of the land available for sunflowers in an RHFA to be planted to sunflowers. Likewise wheat can only be grown in five of eight consecutive years in the OFS/Tvl region. In the Cape, the success of wheat production depends largely on the amount of soil moisture present in the soil at planting. For this reason if wheat is grown in a monoculture it is grown using a wheat fallow rotation. These and other rotation considerations were included in the model.

2.6 Supply of Inputs

The supply of inputs to production activities was assumed to be either perfectly elastic or perfectly inelastic. The supply of land, being a constraint, was considered perfectly inelastic. All other inputs were supplied at a fixed price.

2.7 Risk

The approach developed by Hazell and Scandizzo (1974) was used to include risk in the model. In this study risk was accounted for by the deviations of gross income per hectare from the trend line. With the mean absolute deviation method developed by Hazell and Scandizzo (1974) risk can be included as a cost factor in the objective function. Hazell and Norton (1986:89) provide an example of an LP matrix which explains the inclusion of risk. In this model estimates of the standard deviation were used, a procedure followed by Frank (1986), Ortmann (1985), Nieuwoudt *et al* (1976), and Simmons and Pomareda (1975). Each production region was given its own risk aversion coefficient (θ). This permits "fine tuning" to give the best simulation of farming production in the different regions. There has been criticism for calling θ a risk aversion coefficient. As Hazell (1982) points out, when altering θ to find the "best fit", the value of θ may be biased by model and data errors. Other factors such as incomplete technical and market information, different personal objectives and different subjective expectations may be captured by θ. However, Sonka (1979) states that it may be more important to model the effects of farmers' objectives as a whole, than to measure risk preferences when attempting to estimate future behaviour.

2.8 Risk Data

Many past studies have used aggregated data to estimate variations in the gross incomes over time for different crops. Eisgruber and Schuman (1963) concluded that any computation of a combined variance from aggregated data (eg. in evaluating income stability as related to differing enterprise combinations) may result in a serious distortion of the true situation and lead to faulty conclusions. Atwood *et al* (1986) found that yield variability based on average yields was consistently lower than individual farm variability. However pooled variability tends to be more representative of variability on individual farms. It was also found that relationships observed using average data were outside the range of levels experienced by individual farms and that pooled yield data give correlation coefficients that are "average" of those experienced on the individual farms for all crops.

Yield data for wheat, barley and oats for six different farms were taken from the Mail-in Record System (Directorate of Agricultural Production Economics, 1981 to 1986) for the Rûens region. The yields are presented in Table 1. It is clear that considerable variability in yields exist across years for a given farm and between farms for a given crop.

Table 1 Yields of wheat, barley and oats for six farms in the Rûens, 1981-1986

Farm	Year 1981	1982	1983	1984	1985	1986
Wheat-tons/ha:						
Farm 1	1,60	2,05	2,01	1,75	2,02	2,06
Farm 2	1,10	1,82	1,77	1,78	1,36	1,03
Farm 3	1,41	2,39	1,42	1,69	2,45	2,09
Farm 4	1,63	2,09	2,12	1,88	2,21	1,77
Farm 5	1,40	1,20	1,34	1,84	2,40	1,31
Farm 6	1,46	2,18	2,19	2,34	2,50	2,00
Average	**1,43**	**1,96**	**1,81**	**1,88**	**2,16**	**1,71**
Barley-tons/ha:						
Farm 1	1,74	2,14	2,47	1,86	2,58	2,48
Farm 2	1,52	1,36	2,32	1,86	1,61	1,17
Farm 3	1,89	1,81	2,12	2,59	2,68	2,37
Farm 4	1,54	2,88	2,50	1,99	3,36	2.36
Farm 5	1,56	0,92	1,72	1,51	2,74	1.89
Farm 6	1,96	2,20	2,50	2,38	3,20	2,00
Average	**1,70**	**1,89**	**2,27**	**2,03**	**2,70**	**2,05**
Oats-tons/ha:						
Farm 1	0,42	0,97	0,43	0,58	0,73	0,22
Farm 2	0,11	0,60	1,13	0,58	0,80	2.22
Farm 3	0,86	0,75	1,33	1,85	1,16	1.23
Farm 4	0,42	0,60	3,26	0,94	3,28	2.91
Farm 5	0,22	0,11	0,93	0,90	0,59	1.48
Farm 6	0,13	0,60	1,00	0,22	1,45	0.63
Average	**0,36**	**0,61**	**1,35**	**0,85**	**1,34**	**1,45**

Table 2 presents standard deviations and correlation coefficients for each of the six farms for six years, average yields of the six farms for six years, plus pooled yields. The structure of the pooled data is of a cross sectional-time series nature with farms representing cross sections. Thus there are 36 observations in the pooled data set.

Table 2 Yield standard deviations, correlation coefficients, average yields and pooled yields of wheat, barley and oats for six farms in the Rûens.

Farm	Standard Deviation			Correlation Coefficients		
	Wheat	Barley	Oats	Wheat/ Barley	Wheat/ Oats	Barley/ Oats
1	0,192	0,353	0,264	0,79	0,45	0,05
2	0,368	0,486	0,724	0,58	-0,31	-0,23
3	0,467	0,361	0,389	-0,34	-0,30	0,79
4	0,226	0,642	1,380	0,88	0,49	0,55
5	0,457	0,596	0,508	0,60	0,01	-0,13
6	0,360	0,456	0,493	0,56	0,44	0,82
Average annual Yields	0,245	0,346	0,455	0,78	0,45	0,75
Pooled Yields	0,401	0,546	0,816	0,55	-0,02	0,21

Considerable differences exist among farms with respect to yield standard deviation. The range of standard deviation for wheat is from 0,192 for farm 1 to 0,467 for farm 3. The range for barley is from 0,353 for farm 1 to 0,642 for farm 4. For oats the range is from 0,264 for farm 1 to 1,38 for farm 4. From the data farm 1 seems to have a consistently low yield variability and farms 4 and 5 a high yield variability.

As mentioned earlier, yield variability based on average yields is expected to be lower than individual farm variability. This is highlighted here especially in the case of barley where the average variability is lower than for any of the individual farms. However, pooled yield variability tends to be representative of the "average" variability of individual farms.

Significant differences in relationships are observed among farms. Correlation coefficients for wheat and barley range from -0,34 for farm 3 to 0,88 for farm 4. Wheat and oats yield correlation coefficients ranging from -0,31 for farm 2 to 0,49 for farm 4. For barley and oats the range is from -0,23 for farm 2 to 0,82 for farm 6. It appears that the correlation coefficients for average yields are biased upwards when comparing them to individual correlation coefficients. For example, the average correlation coefficient for wheat/oats is 0,45 yet only one farm (farm 4) has a correlation coefficient slightly greater than this. It can be seen that the pooled yield data has a correlation coefficient roughly "average" of those experienced on the six farms for the three crops.

In light of these results it was decided to use a pooled data set. Gross incomes for each crop for individual farms were taken from the Mail-in Record System for the Rûens and Swartland production regions (Directorate of Agricultural Production Economics 1981 to 1986). Information from six farms for six years for each production region was used.

A dummy variable model was fitted for each crop's gross income with linear and quadratic slope coefficients for time trend varying across farms.

$$G_{iT} = b_{0i} + b_{1i}T + b_{2i}T^2 + e_{iT} \quad (1)$$

Where:

- G_{iT} = Gross income on the ith farm at time T.
- b_{0i} = The intercept for the ith farm.
- b_{1i} = The linear slope coefficient for the ith farm.
- b_{2i} = The quadratic slope coefficient for the ith farm.
- e_{iT} = Residual error for the ith farm at time T.

The method used to estimate equation 1 was ordinary least squares. Different intercepts for the individual farms were taken to represent different management practices, soil types and other environmental influences on gross incomes which did not interact with time. Different slope coefficients were taken to indicate differences in technology over time and would also adjust for inflation of gross incomes over time.

A dummy with a coefficient significant at the one percent level or less was included in the model with the other dummies being dropped from the model. The model was then re-run to check that the remaining dummies were still significant. If so, the residuals of this model were used as risk data. If no dummy intercept or slope coefficient was significant, then deviations were taken from the common time trend line. Thus, the gross incomes for that particular crop for all farms were assumed to be generated by a process common to all farms. If the common linear and quadratic time effects were not significant then deviations from the arithmetic mean of the gross incomes were taken.

As individual farm data were not available for the OFS/Tvl region, aggregated data for nine years from the Department of Statistics (1975/84), were used.

2.9 Demand

Price elasticity of demand estimates were obtained for each crop. Table 3 gives various elasticity estimates and the coefficients used in the model.

Table 3: Estimates of price elasticities of demand.

Crop	Elasticity	Source
Wheat	-0,522 (bread)	Darroch (1983:12)
	-0,65*	Richardson(1976:38)
Maize	-0,513	Frank (1986:39)
(human)	-0,33	Cadiz (1984:10)
	-0,1 to 0,15	Van Zyl (1985:14)
Maize	-0,885	Frank (1986:39)
(animal)	-1,12	Cadiz (1984:21)
	-3,0	Nieuwoudt (1973:38)
	-1,29 to -1,59	Van Zyl (1985:13)
Maize (weighted average of human and animal)	-0,725*	Estimate
Maize/Wheat (Cross-elasticity)	0,2*	Van Zyl (1985)
Sorghum	-0,9*	Nieuwoudt *al* (1976:486)
Sunflower	-7,04*(Food oil)	Sheppard (1968:62)
Oats	-0,007	Sheppard (1968:62)
	-0,5*	Estimate

* Estimates used in LP model

These estimates were transformed into demand functions. The area beneath the demand function (P = a - bQ) is given by the integral of the function as follows :

$$W = Q(a - 0.5bQ) \quad (2)$$

Where : P = product price.
a = constant.
b = slope of the function.
Q = aggregate quantity demanded
W = area beneath the demand function (total welfare)

This function is not linear so it cannot be entered directly into a linear program. However, it can be linearized by using the Duloy and Norton (1973) technique : the demand function is divided into segments and the area beneath the demand function up to each consecutive segment is calculated. The welfare values for different quantities are then calculated. These welfare values were used in the objective row of the LP matrix to enable total consumer surplus to be maximised. Each segment is then entered into the LP matrix as a separate activity, but a constraint ensures that only one of these activities enters the solution at any one time.

Regional demand functions were estimated for those crops where only a percentage of the total crop is grown in the wheat-growing regions. This was done by utilising the method proposed by Kutcher (1972) and used by Ortmann (1985) and Frank (1986).

The welfare values calculated hold if there is no substitution in demand. However, there appears to be a significant cross-elasticity between the demand for maize and wheat. Van Zyl (1985) estimated this cross-price elasticity to be 0,2. The quantities and welfares of the consumption of maize and wheat were calculated at different prices for the two crops. Total welfare was calculated by adding the individual welfares derived from maize and wheat consumption at different prices. The total welfare vector was entered into the objective function of the matrix.

Export demands were assumed to be perfectly elastic due to South Africa's small share of world markets. Shifts in demand due to changes in income were ignored.

2.10 The model

The objective function of the model can now be expressed as follows :

$$\text{Max } Z = [\,X'M\,(A-0.5BMX)] - \sum_{i=1}^{N}\{[C'X]_i + [\theta_i(X'\Omega X)^{0.5}]_i\} \quad (3)$$

The first term of equation 3 measures total welfare, which is the integral of the linear product demand function P = A - BMX, where M is a nxn diagonal matrix of average yields per hectare and X is a nxl vector of aggregate hectares generated endogenously within the model. Production costs are deducted in the second term [C'X] where C is a vector of production costs per hectare. Costs associated with risk are deducted in the last term, where Ω is a variance-covariance matrix of gross incomes per hectare, θ_i is an aggregate "risk aversion" coefficient for all farms in region i and N the number of major regions (three in this study).

3. Simulation

Before the model can be used to evaluate alternative wheat policies, results must be compared with present cropping patterns. This also provides a check on cost data. To do this, current policies relevant to the different crops were imposed on the model. Wheat, maize , barley and oats were (during 1981 to 1986) all marketed through a one-channel fixed price scheme. Sorghum and sunflowers were marketed under a floor-price and pool-price scheme respectively. However, relatively small quantities of sorghum and sunflowers are produced in the wheat regions. Therefore, for the purpose of simulation, demand curves for these crops were assumed to be perfectly elastic. The average producer prices from 1981 to 1986, inflated by the consumer price index to 1986 rand, were used for all crops.

Three tests for simulation were used, namely, land areas, regional production and land rents. Sensitivity of the optimal solution was determined by using different values of θ. Table 4 gives production hectares with different risk aversion coefficients. Correlation coefficients and percentage absolute deviations (PAD) are given for the individual production regions and the three regions combined, for different values of θ. According to Hazell and Norton (1986: 271) an overall PAD of less than 15 per cent is acceptable. For the OFS/Tvl region a θ value of 0,30 results in the "best fit" giving a correlation coefficient of 0,998 and a PAD of 4,1 per cent . An increase in θ results in a decrease in the area planted to maize with diversification into the planting of competing crops.

Table 4: Areas planted under different risk aversion coefficients

Region	Actual ha (1000's)	Simulated Ha(1000's) at		
OFS/Tvl		θ=0,10	θ=0,30	θ=0,50
Wheat	908,9	570,0	832,8	865,9
Maize	1172,8	1528,7	1179,1	930,6
Sorghum	45,3	0,0	48,9	61,2
Sunflower	90,7	50,2	88,1	161,6
Oats	18,5	15,0	15,0	15,0
Corr, Coefficient		0,934	0,998	0,990
PAD		35,1%	4,1%	16,8%
Swartland		θ=0,25	θ=0,35	θ=0,50
Wheat	356,4	390,6	390,6	279,0
Oats	44,6	98,0	77,0	109,9
Pastures	9,6	0,0	21,0	174,1
Fallow	253,4	227,6	227,6	153,2
Corr, Coefficient		0,975	0,985	0,723
PAD		18,5%	15,6%	61,4%
Rûens		θ=0,50	θ=0,60	θ=1,00
Wheat	218,0	239,7	194,6	179,8
Barley	92,0	77,7	87,5	88,6
Oats	15,0	13,7	13,7	0,0
Pastures	185,0	83,0	208,3	238,0
Fallow	117,0	213.6	123.5	121,3
Corr, Coefficient		0,685	0,976	0,926
PAD		37,6%	9,4%	18,2%
Overall Corr, Coef,		0,937	0,997	0,976
Overall PAD		32,4%	12,2%	28,9%

PAD - Percentage Absolute Deviation

For the Swartland a θ value of 0,35 gives a correlation coefficient and PAD of 0,985 and 15,6 per cent respectively. These relatively poor results can be attributed to the lack of viable alternative crops other than wheat that can be grown in this region. Therefore the model tends to specialise and simulates the crops produced on small areas poorly.

Table 5: Production under different risk aversion (1000t)

Region	Actual Production	Simulated Production at		
OFS/Tvl		θ=0,10	θ=0,30	θ=0,50
Wheat	813,9	558,3	806,0	835,1
Maize	1955,8	2572,6	2021,9	1672,0
Sorghum	26,8	0,0	73,3	94,6
Sunflower	72,7	58,4	97,1	167,0
Oats	20,3	22,5	22,5	22,5
Corr, Coefficient		0,979	0,999	0,996
PAD		31,7 %	5,1%	16,2%
Swartland		θ=0,25	θ=0,35	θ=0,50
Wheat	354,4	359,8	359,8	271,3
Oats	10,8	104,3	81,2	116,1
PAD		27,1%	20,7%	51,6%
Rûens		θ=0,50	θ=0,60	θ=1,00
Wheat	273,4	348,4	278,2	259,4
Barley	107,8	91,6	109,5	110,9
Oats	15,8	15,1	15,1	0,0
PAD		23,2%	1,8%	8,3%
Overall Corr, Coef,		0,979	0,999	0,994
Overall PAD		30,3%	6,3%	18,9%

PAD - Percentage absolute deviation.

For the Rûens region a θ value of 0,60 results in the best correlation coefficient and PAD of 0,976 and 9,4 per cent respectively. An increase in θ results in a decrease in the area of wheat and oats and an increase in the area of barley and pastures. The overall correlation coefficient and PAD are good, being 0,997 and 12,2 per cent respectively.

The results of the second test are shown in Table 5. The production of different crops in the OFS/Tvl region is simulated closely at the optimum θ value (0,30) giving a correlation coefficient and PAD of 0,999 and 5,1 per cent respectively. Simulation of production in the Swartland region is poor which is mainly due to the poor simulation of oats production. One reason for this is that the actual production figure recorded does not account for oats produced but fed to livestock. If this data were available there would be an improvement in the PAD for the Swartland region. The production of wheat, barley and oats in the Rûens region is simulated closely at the optimum θ value (0,60). The overall PAD value of 6,3 per cent indicates that close simulation was obtained.

Interesting to note is that the production of wheat in the Swartland and Rûens regions decreases with an increase in θ, but increases in the OFS/Tvl region, highlighting the differences in wheat production in the winter rainfall region compared to the summer rainfall region.

Estimates of actual rent data were acquired from regional extension officers and economists in the different production regions (Coetzee 1987; Laubsher 1987; Purchase 1987). Results of the land-rent test are presented in Table 6.

The fact that the shadow prices of land at the optimum θ values are similar to the actual rents, shows that the costs used in the model are representative of the real production costs.

Table 6: Actual rents and estimated rents per hectare at different risk aversion coefficients (1986)

Region	Actual Rents(R/Ha)	Simulated Shadow Price of Land (R/Ha)		
		θ=0,10	θ=0,30	θ=0,50
OFS	80-90	104,65	81,95	64,62
		θ=0,25	θ=0,35	θ=0,5
Swartland	70-80	76,23	70,17	61,87
		θ=0,50	θ=0,60	θ=1,00
Rûens	90-110	118,28	92,32	68,49

From the overall correlation coefficient and PAD tests the simulation exercise was reasonably successful, the optimum θ levels being 0,30, 0,35, and 0,60 for the OFS/Tvl, Swartland and Rûens regions respectively. These θ values compare with past studies. Nieuwoudt *et al* (1976) reported a value of 2,0 as giving the best solution in simulating peanut production in the U.S.A. Ortmann (1985) found that θ equal to 0,25 gave the best results in simulating sugar-cane production in South Africa. Frank (1986) found that θ equal to 0,55 gave the best solution in simulating maize production in South Africa.

4. Conclusion

A mathematical programming model of the wheat industry was developed, with the objective of comparing different policy options for wheat marketing in South Africa. Substitution in supply was modeled by including alternative crops to wheat in each of the production regions. To make the model more realistic crop rotations were incorporated in the model. Risk in the form of variance-covariance matrices was also considered. Pooled data appear to give more representative variances within and correlation coefficients between crops than aggregated data in risk analysis. Negative-sloping demand curves for the main crops, which incorporated substitution in demand between wheat and maize, were also considered.

The values of the risk aversion coefficients that gave the "best fit" for simulation were 0,30, 0,35 and 0,60 for the OFS/Tvl, Swartland and Rûens regions respectively. These gave an overall correlation coefficient and PAD of 0,997 and 12,2 per cent respectively for actual land and predicted land usage. The overall correlation coefficient and PAD for actual production and predicted production was 0,999 and 6,3 per cent respectively. These correlation coefficients and PADs indicate that the wheat industry has been adequately simulated and that the model should be reliable in predicting the effects of various wheat marketing programmes. Results of these predictions are presented in Howcroft (1990).

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