AGRICULTURAL COMPARATIVE ADVANTAGES IN DEVELOPMENT REGION G OF SOUTH AFRICA: AN APPLICATION OF A REGIONAL LINEAR PROGRAMMING MODEL[1]

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Abstract

The purpose of this article is to model the agricultural production sector of Region G to determine whether Development Region G of South Africa has comparative advantages with respect to the production of certain agricultural commodities. The analysis is based on an application of an advanced regional linear programming model. With the present marketing system production of fruit and vegetables, livestock and livestock products, and animal feeds, e.g. soya beans, should be expanded. On the other hand, production of staples, e.g. maize and wheat, and other summer cash crops should be scaled down. Under a free market system there also seems to be, apart from the commodities already mentioned above, a comparative advantage for specifically dryland staple food production.

1. Introduction

The purpose of this article is to model the agricultural production sector of Region G to determine whether Region G has comparative advantages with respect to the production of certain commodities. This will enable the determination of desired increases and decreases in production of agricultural commodities in Region G. The analysis is based on an application of an advanced regional linear programming model. This is described in detail by Hazell & Norton (1986), and follows that of Scandizzo & Bruce (1980); Duloy & Norton (1973) and Bassoco & Norton (1983).

The selection of the most important commodities in Region G for the analysis was based on a detailed analysis of the 1989 DBSA statistical base by applying the following criteria:

- Broad land-use pattern;
- area and gross value of production by main commodity group;
- area and gross value of production per commodity; and
- import and export potential of agricultural products.

Based on these criteria, the following 18 commodities were selected for further study in this article: maize, wheat, cotton, soya beans, groundnuts, sunflowers, citrus, table grapes, macadamia nuts, avocados, bananas, mangos, potatoes, tomatoes, broilers, cattle, goats and milk (for a detailed analysis of how these commodities were selected, see Meyer, 1992).

2. Model development

2.1 Introduction

Having selected the major commodities produced in Region G, the task is to assemble a linear programming matrix in order to model the agricultural sector. The model was developed over three stages (see Ortmann, 1988; Hazell & Norton, 1986): First, the basic model with costs and fixed prices only was assembled with 1989 as base year. Next, risk was included using MOTAD and finally, variable product prices were modelled by using stepped demand functions. Each of these three stages will be described.

2.2 Basic model

In a perfect model, each farm is modelled independently with its own unique set of production conditions. However, when production conditions over an area are similar then that area can be treated as one activity. The first problem therefore is to identify homogenous regions, i.e., areas of similar yields and costs per hectare. For purposes of this paper Region G was divided into the six areas according to certain criteria (sub-regions 1-6: see Meyer, 1992, for a detailed description of each sub-region). Each of these were again subdivided into three areas, namely dryland, irrigation, and natural pastures. Ultimately, Region G was divided into 18 resource regions.

It is important to identify those commodities which compete for land and other resources so that the alternatives that face the farmer are also specified in the computer model. In this way, substitution in supply is included in the model. The eighteen agricultural commodities described in Section 1 were all included in the model. The supply of each commodity is upward sloping because costs differ between areas and because the crops compete with one another for land within regions.

Land use, area, production, yields, prices, costs and gross margins for the selected crop commodities used in the model were derived from the work of Meyer (1992). This includes the data for the livestock commodities. These data vary for the same commodity between sub-regions, as well as between land quality, e.g. dryland and irrigation.

The supply of inputs to the production activities is assumed to be either perfectly elastic or perfectly inelastic. The supply of land is assumed to be perfectly inelastic. Land is therefore a constraint. All other inputs are supplied at a fixed price. These rigorous assumptions are plausible: if all arable land in Region G is currently under these commodities then no matter how much the rent for this land increases the quantity is fixed. Most inputs for agriculture are manufactured goods which can be increased in supply substantially without any additional cost per unit (e.g., fertilizer, tractors and fuel). Furthermore, Region G constitutes only a portion of South African agriculture as a whole and can therefore attract resources away from other sectors with small price increases. It can be argued that labour supply must have an upward sloping supply curve since farmers have to increase wages in order to attract more workers to the farming sector in their region. Ortmann (1985) and Nieuwoudt *et al.* (1976) refined their models by including upward sloping supply functions for labour. In this study, however, labour supply is assumed to be perfectly elastic. This should not cause serious errors because the elasticity is very high due to the abundance of labour in South Africa (Ortmann used an elasticity of 10). This assumption is also plausible if one takes into account that the unemployment rate is in excess of 25 per cent in the rural areas of Southern Africa (Van Zyl & Vink, 1988; Naledzani; 1992).

The total amount of arable land available in Region G was simply taken to be the sum of the areas utilized for the commodities. Any additional arable land that might be available is assumed to be negligible or unavailable for these commodities. In the developing areas the total amount of arable land available was taken to be the sum of the areas planted to commercial and subsistence commodities.

2.3 Risk data

In this section, the basic model described in the previous section is refined by including risk considerations according to the MOTAD method (Hazell & Norton, 1986). Farmers base their cropping decisions not only on the profitability of each crop, but also on the crop's riskiness. There are three main sources of risk: yield uncertainty, price uncertainty and cost uncertainty. In this study gross income variations are used as a measure of risk because of the lack of time series cost data.

Yield data were not used in the yield component of gross incomes because it was desirable to include the drought years in order to fully account for risk. Yield data from 1980 to 1989 were used for this purpose. Deviations from the mean, rather than the trend, were used.

The question of whether gross income deviations over the past ten years is an adequate measure of risk faced by farmers must be considered. There are other sources of risk : input cost variations, credit uncertainty or machinery breakdowns. However, it is well known that uncertainty associated with the weather, reflected in yields, is by far the most important source of risk, followed by price uncertainty. The model assumes that farmers base their future expectations of risk on an equal weighting of the past ten years' gross incomes. A heavier weighting on more recent years and a period longer than ten years may have been more correct. By including the drought years, risk may have been overstated.

Because areas which have higher gross income values tend to have higher standard deviations, it may have been more correct to divide each deviation by its mean to partially standardize the data. However, this would corrupt the risk aversion coefficient.

2.4 Stepped demand functions

This section describes a technique whereby the demand for each product is modelled enabling the endogenous generation of equilibrium prices. In order to use this technique elasticity estimates for each crop for each of its uses (e.g. animal demand, human demand and export demand), and the current mean quantity consumed and the price, are the data requirements.

The Linear Programming model actually requires flexibility rather than elasticity estimates, but because with some of these commodities quantity is a function of price, only elasticity estimates can be made. The inverse of the elasticity equals the flexibility only if there are no cross elasticities and R^2 is 100 per cent (Tomek & Robinson, 1981:67). As this is clearly not the case, all of the flexibility estimates are biased downward because the reciprocal of the elasticity sets the lower limit of the flexibility. However, using the inverse of the elasticity as a flexibility estimate appears to be an acceptable practice judging by the number of writers that have done this, for example, Hazell & Norton (1986).

A review of the different elasticities of demand was made, while others were calculated by Meyer (1992). Region G only contributes part of South Africa's total production. This necessitates the calculation of a **regional** demand function for the commodities. To merely shift the national demand function inwards to the extent of the quantity difference is not sufficient because regional demand will be more elastic than national demand. Kutcher (1972), cited by Ortmann (1985), shows how regional demand functions can be derived from national demand functions. This method was also employed in this article to elicit regional demand elasticities.

Given the elasticity of demand, and the mean price and quantity, the demand function and the consumer surplus associated with any quantity were calculated. These values were used to calculate prices, producer income and welfare values for different quantities of the mean quantity consumed. These welfare values were used in the objective row of the matrix to enable total surplus to be maximized.

Changes in income cause shifts in the demand for most goods. However, if the change in agricultural income indicated by the model's solutions is a sufficiently small part of income in the entire economy then it would be safe to ignore income effects. The summer grains industry contributes less than 3 per cent to GDP (Abstract of Agricultural Statistics, 1992), therefore a change in the incomes in this sector will have a negligible effect on total income.

2.5 Summary

In this section the linear programming model was developed to a fairly high degree of sophistication. Substitution in supply was modelled by including alternative commodities in each of the resource regions. Allowance was made for producer risk aversion by using MOTAD. This technique has the additional advantage of acting as a "fine-tuning" device when simulation is attempted. It will also encourage crop diversification in regions, making the solutions more realistic. Demand functions were incorporated into the model by using elasticity estimates and the current prices and quantities. Most of these were downward sloping and therefore needed to be linearized by dividing them into steps. Substitution in demand was modelled by using the same technique. This linear programming technique uses stepped demand and supply functions which causes the solutions to be discontinuous or discrete. This may cause the model to be insensitive, especially if the steps are large. However, in this model there are 18 resource regions, and 20 steps in the demand functions which should cause it to be adequately sensitive.

3. Model validation and calibration

The next step is to test the model. This is done by imposing all of the policies which are currently in operation (base year is 1989) on the model to see if it will simulate the current situation. The degree to which the model simulates the current situation is a measure of its reliability. If simulation is good, then one can have confidence in the model's ability to compare various policies.

Two tests were used for simulation, namely: 1) Regional production; and 2) Product prices. Each test compares a particular set of parameters generated by the model with **actual** base year values (1989). The quantities of various commodities produced in each region changes with different risk aversion coefficients. As the risk aversion coefficient increased so more risky crops like dryland maize decreased and animal production increased. The best simulation, indicated by the correlation coefficients, was obtained with a Θ-value of 0,25. The second test compared actual current prices with dual prices generated by the model. Here too, a Θ-value of 0,25 gives the best "fit". This is expected because there is a purely linear relationship between prices and quantities.

The "risk aversion coefficient" (Θ) of 0,25 compares favourably with other studies: It is the same as the one derived by Ortmann (1985), slightly less than the Θ-values of repectively 0,43 obtained by Van Zyl, Fényes and Vink (1992) and of 2,0 obtained by Nieuwoudt *et al.* (1976). However, not much emphasis need be placed on this value. Rather, the correlation coefficients indicate that the current situation has been adequately simulated and that the model should be reliable. This enables the study to continue to the application stage.

4. Application of the model

4.1 Introduction

The application stage of the model is divided into two sections, namely:

i) Firstly, the "optimal" situation from a normative viewpoint, is determined by comparing the base values determined by the model with actual values as encountered in 1989 (Scenario A). This provides an indication of the direction into which production of the different commodities should move.

ii) Secondly, results obtained with a free market for all products are compared with base values and solutions in order to determine areas of comparative advantages and shadow prices, reflecting the real value of agricultural production in Region G to the South African population when there is no market distortions (Scenario B). The solution to a free market policy for all commodities is presented here as a "benchmark" policy. It is the only policy where social costs are zero. The free market policy highlights how other policies distort production and consumption patterns.

Three important assumptions must be borne in mind while interpreting these results: Firstly, the model is static, hence industries do not react to changes other than these specified in the model. Secondly, adjustment is frictionless and costless, meaning that solutions are long-run predictions. Thirdly, the industries are protected from foreign imports.

Criteria used to compare policies are total production, commodity prices and social costs and benefits.

4.2 Results

Table 1 presents the results with respect to changes in total production of the different commodities given the two scenarios as described above, while Table 2 shows the changes in prices of the selected commodities given the different scenarios. Table 3 presents the changes in producer and consumer welfare produced by the equilibrium solutions provided by the model in Scenarios A and B.

4.3 Discussion

4.3.1 Scenario A

The results in Table 1 indicate that with the present marketing system, there should be a marked decrease in the production of maize, wheat under irrigation, cotton under irrigation, sunflowers and groundnuts under irrigation. However, production of soya beans, dryland groundnuts, fruit under irrigation (citrus, table grapes, macadamia nuts, avocados, bananas and mangos), potatoes, and livestock and livestock products (broilers, cattle and goats slaughtered, and milk) should increase by at least 5 per cent. This indicates that Region G should concentrate on the production of fruit and vegetables under irrigation, while moving away from the production of basic staples such as maize and other cash crops, especially under irrigation. Livestock production also seems to be an area where growth is desirable.

Table 2 shows that there will only be limited and relatively insignificant changes in prices of the different commodities under the present marketing system. This means that the production changes discussed above (Table 1) will have an insignificant and negligible effect on product prices. Sunflowers, however, seem to be an exception.

According to Table 3, the above production and price effects will culminate in an increase in welfare for both producers (12,9 per cent) and consumers (2,3 percent) in Region G. Total welfare for Region G will increase by 3,7 per cent.

4.3.2 Scenario B

Scenario B, which represents a free market for all the commodities specified in the model, gives an indication of how present marketing policies have distorted production and prices. As has been indicated, under a free market system there are no social costs; Scenario B can thus be seen as a "benchmark" policy.

Table 1: Changes in production of the selected commodities in Region G under different scenarios

Product	Land-use	Actual production (1989)		Scenario A: Change in actual production with present marketing system (%)	Scenario B: Change in actual production with free marketing system (%)
		Quantity	Unit		
Maize	Dryland	120538	Tons	-18.4	+1.3
	Irrigation	38065	Tons	-16.5	-14.2
Wheat	Dryland	23989	Tons	+0.5	+15.9
	Irrigation	48704	Tons	-7.4	-14.1
Cotton	Dryland	56235	Tons	+2.7	-10.5
	Irrigation	24101	Tons	-16.3	-8.2
Soya beans	Dryland	2338	Tons	+32.8	+16.6
	Irrigation	7015	Tons	+11.2	+5.4
Groundnuts	Dryland	14403	Tons	+7.3	-9.1
	Irrigation	1964	Tons	-4.6	-23.7
Sunflowers	Dryland	33953	Tons	-11.4	-33.6
	Irrigation	3773	Tons	-88.5	-85.7
Citrus	Irrigation	282084	Tons	+17.6	+19.3
Table grapes	Irrigation	5460	Tons	+5.7	+5.9
Macadamia nuts	Irrigation	1532	Tons	+4.1	+6.7
Avocados	Irrigation	22923	Tons	+16.3	+17.4
Bananas	Irrigation	163591	Tons	+7.1	+6.4
Mangos	Irrigation	26658	Tons	+13.5	+14.8
Potatoes	Irrigation	195121	Tons	+4.5	+5.3
Tomatoes	Irrigation	124528	Tons	+2.0	+1.9
Broilers	-	7318217	Birds	+21.3	+29.8
Cattle slaughtered	-	33981	Tons	+16.1	+12.0
Goats slaughtered	-	556	Tons	+22.9	+15.4
Milk	-	25145	Kilolitre	+14.8	+11.5

Table 1 shows that under a free market policy maize and wheat production under irrigation will decrease, but especially wheat will increase considerably on dryland. Production of soya beans will also increase considerably, but production of cotton, groundnuts and sunflower will decrease. The latter crops are displaced by dryland maize and wheat. Fruit and vegetable production under irrigation will increase significantly. This applies to all the products in these categories, namely citrus, table grapes, macadamias, avocados, bananas, mangoes, potatoes and tomatoes. Production of livestock and livestock products, especially broilers, will increase considerably, given a free market scenario. According to Table 2 prices of maize, wheat and soya beans in Region G will increase under a free market system, while that of cotton, groundnuts and sunflowers will decrease. This is due to a decrease in production of maize and wheat in the other areas of South Africa, and an increase in the production of the other commodities which are production substitutes for wheat and maize, especially in the summer rainfall area. Fruit prices in Region G, with the exception of table grapes and macadamias, will decline under a free market. This is mainly due to an increase in production of these products, especially the increase that will take place in Region G. Prices of broilers and milk in Region G will decrease, while prices of red meat will increase.

Table 2: Changes in prices of the selected commodities in Region G under different scenarios

Product	Actual prices (1989)		Scenario A: Change in actual prices with present marketing system (%)	Scenario B: Change in actual prices with free marketing system (%)
	Value (R)	Unit		
Maize	240.00	Tons	0.0	+6.5
Wheat	350.00	Tons	0.0	+3.4
Cotton	998.94	Tons	-0.1	-9.2
Soya beans	537.92	Tons	-0.2	+11.8
Groundnuts	790.90	Tons	-0.4	-6.8
Sunflowers	543.25	Tons	+2.3	-14.9
Citrus	485.63	Tons	-0.7	-2.7
Table grapes	1165.00	Tons	+1.6	+1.3
Macadamias	2137.42	Tons	+2.3	+2.5
Avocados	1106.00	Tons	+0.2	-0.2
Bananas	595.00	Tons	+1.7	-3.4
Mangoes	1066.00	Tons	-7.7	-8.5
Potatoes	380.00	Tons	-2.5	-4.9
Tomatoes	560.00	Tons	-0.7	-1.6
Broilers	5.10	Birds	0.0	-6.3
Cattle slaughtered	4214.27	Tons	0.0	+7.6
Goats slaughtered	3131.49	Tons	0.0	+8.3
Milk	501.44	Kilolitre	0.0	-11.9

Table 3: Welfare changes in Region G under different scenarios

ITEM	SCENARIO A (Current marketing system) (%)	SCENARIO B (Free market for all commodities) (%)
Producers (1)	+12.9	+14.7
Consumers (2)	+2.3	+4.9
Total (1+2)	+3.7	+5.4

Table 3 illustrates the social cost of the present system: With a free market for all products, total welfare in Region G will increase by 5,4 per cent. This is made up by increases in welfare of both producers (14,7 per cent) and consumers (4,9 per cent).

5. Synopsis

The above results highlight the areas of comparative advantage and recommended growth for Region G:

- With the present marketing system production of fruit and vegetables, livestock and livestock products, and animal feeds, e.g. soya beans, should in general be expanded. On the other hand, production of staples, e.g. maize and wheat, and other summer cash crops should in general be scaled down.

- Under a free market system there also seems to be, apart from the commodities already mentioned above, a comparative advantage for specifically dryland staple food production. This is due to the large number of people residing in Region G and the relatively low food production which necessitates food imports into Region G.

The present marketing system for wheat and maize, which allows for a fixed price system for maize and wheat under the Marketing Act, thus does not benefit the producers and consumers of Region G. Even though Region G is a net importer of maize and wheat due to its relatively large population, producers in Region G cross subsidize producers in other regions of South Africa to artificially drive down their own producer prices, and increase consumer prices due to high transport costs. A free market will thus benefit especially the consumers and producers of wheat and maize.

Note

1. Based on a MSc(Agric) dissertation in agricultural economics at the University of Pretoria.

2. Presently from the Development Bank of Southern Africa.

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