THE EFFECTS OF WATER POLICIES ON THE FARM SECTOR IN THE WESTERN CAPE

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The farm sector of the Western Cape is modelled using a sector mathematical programming model to determine the effect of different water policies on output, prices, welfare and employment. Two scenarios are analysed, namely the effect of a restriction of water available for irrigation, and an increase in water tariffs. Results show a relative shift away from (intensive) irrigated production, and a decrease in producer welfare, especially for irrigation farmers, under both scenarios. When water availability is decreased, the negative effect falls disproportionately on the poor as employment decreases. In the long run the negative effects are severe, as there is a relative shift out of industries where the Western Cape has a competitive advantage.

DIE UITWERKINGS VAN WATERBELEIDE OP DIE PLAASSEKTOR IN DIE WES-KAAP

Die plaassektor van die Wes-Kaap is gemodelleer met die gebruik van 'n wiskundige programmeringsmodel teneinde die effek van verskillende waterbeleide op produksie, welvaart en indiensneming te bepaal. Twee scenarios word ntleed, naamlik die effek van 'n beperking op die water beskikbaar vir besproeiing en 'n verhoging van watertariewe. Die resultate toon 'n beweging weg van (intensiewe) besproeide produksie en 'n afname in produsentewelvaart, veral vir besproeiingsboere, onder beide scenarios. Wanneer waterbeskikbaarheid verminder word tref die negatiewe effekte veral die armes met 'n afname in indiensname. Oor die langtermyn is die effekte ernstig aangesien daar 'n relatiewe verskuiwing is weg van bedrywe waarin die Wes-Kaap 'n mededingende voordeel het.

1. INTRODUCTION

The theory for the construction of sector mathematical programming models has been applied to South African agriculture on a number of occasions[2]. In this paper, these procedures are used to model the Western Cape farm sector to determine the effects of different water policies. Due to time and other constraints, Western Cape agriculture is modelled using 1988 census reports (CSS, 1993), which appeared in June 1993, as basis. A number of more recent features of the economy are, however, modelled onto this base, as is shown

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[2] *The model construction is described in a report to the Development Bank of Southern Africa by Van Zyl (1995) which summarises much of the relevant theoretical literature. South African applications include Ortmann, 1985; Frank, 1986; Van Zyl, 1987; 1989a; 1989b; Howcroft, 1991; Van Zyl et al, 1991.; Meyer and Van Zyl, 1992.*

below.

2. BUILDING THE MODEL

2.1 Basic considerations

The construction of the model was done in three phases. First, the basic model with costs and fixed prices only was assembled. Next, risk was included by the mean absolute deviation method (MOTAD). Finally, variable product and input prices were modelled by using stepped demand functions, respectively.

Ideally, each farm in a region should be modelled independently, with its own unique set of production conditions. However, this is hardly feasible and not necessary when production conditions are broadly homogeneous over an area. In this model the Western Cape has been divided into ten relatively homogeneous regions, following the Statistical Regions constituting the former Development Region A of South Africa, but putting together a new Region 10 and leaving out the districts which were incorporated into the new Northern Cape Province (the Western Cape region modelled here thus closely approximates the Western Cape Province as defined in the 1997 Constitution).

Two import and export 'regions' were also included, namely Cape Town for international imports and exports and Beaufort West for domestic trade in South Africa. Commodities can be produced in any of the ten resource regions, or imported from the international market or the rest of South Africa. Similarly, commodities are either consumed in the region (on the consumption side no differentiation is made between the regions), or exported to the international market or to the rest of South Africa.

It is important to identify those commodities that compete for land and other resources so that the alternative production possibilities that face the farmer are also specified in the computer model. In this way, substitution in supply is included in the analysis. The 20 major agricultural commodities produced in the Western Cape were selected as production alternatives in this particular application. These commodities were selected on the basis of their contribution to gross farm income, as well as the land allocated to them. The selected commodities account for more than 90 per cent of the total agricultural land used in the region, and more than 85 per cent of the gross value of agricultural production.

Because there is a constraint for land in each area the model generates shadow prices for land if all the land is used. It is assumed that farmers employ a resource until its marginal revenue equals its price within a given set of physical, financial and institutional constraints. Therefore, the shadow price of land serves as a check on the model, because these shadow prices can be compared with the rental value of land. Labour and credit were assumed to be freely available, albeit at an increased cost for increasing amounts. Supply elasticities of 5 and 6, respectively, were assumed.

Water is included as a conventional input into irrigation farming at existing price levels, while the total availability of irrigation water is set as the outer limit to irrigation use. This allows manipulation of both the price of water (the tariff) as well as the total availability of irrigation stocks. In the former case a change in water tariffs will affect net farm income, and therefore the objective function of the model. In the latter case the model optimises using a different total availability of water as a binding constraint.

2.2 Risk

Since Freund's (1956) article on the inclusion of risk in a programming model, rapid developments have occurred in techniques for incorporating risk, particularly in single-period optimisation models (Hazell, 1982). Evidence suggests that farmers behave in a risk-averse manner (Young, 1979:1065). Neglect of risk can lead to considerable overstatement of the size of risky enterprises. Risk can be considered as a cost, namely the additional expected return that farmers want as compensation for taking risk (Barry & Fraser, 1976:288). Risk associated with various enterprises may be taken as the deviations of gross income per hectare from the mean or from the trend line over time (at least six years) as the enterprise price elasticities relate price and yield variability to income variability. The mean absolute deviation method (MOTAD), first proposed by Hazell (1971) and later developed by Hazell & Scandizzo (1974), was used in this application. Income variations during the six year period 1982 to 1988 were used to model the production risk associated with production of each of the commodities in each of the ten regions.

2.3 Structure of the final model

Transport opportunities/activities link the supply and demand sections of the model. Each of the thirteen resource regions or two import 'harbours' can supply any of the three consumption points, namely the Western Cape as a whole, and the two export 'harbours' (Cape Town and Beaufort West). Supply and demand for each region is treated as if it is coming from a specific point rather than from all over a region. This is done to make the representation of transport costs between and within resource regions easier. Consumption and production points were subsequently developed to facilitate this treatment. This is in line with the assumption that production practices, yields, risk and prices are the same within each of the regions.

The final model has 200 production activities (20 commodities in 10 regions); 24 import activities (12 commodities with two import points); 624 transport activities (200 production activities transported to 3 consumption areas, and 24 import activities); 42 demand schedules (of which 24 consist of 10 steps each), and 6 years of risk data for each commodity in each region. In addition, the model was structured to allow for the easy measurement of producer, consumer and total welfare, which form part of the different objective functions, depending on the scenario followed.

3. MODEL VALIDATION

Validation of the model is a process that leads to: (1) a numerical report of the model's fidelity to the historical data set; (2) improvements to the model in the case of imperfect validation; (3) a qualitative judgement on the reliability of the model in terms of its stated purposes; and (4) a conclusion (preferably explicit) concerning the kinds of uses that it should not be used for (Hazell and Norton, 1986). Validation begins with a series of comparisons of model results with the reported actual values of the variables.

Production is the variable most commonly used in validation tests, and for a number of agricultural models there are reported validation results that can be used for comparative purposes. Typically, there is considerable variation in the closeness of the fit to the historical data across different products, and the model builder may be willing to accept greater deviations in minor products if the predictions are good for the major products. There is no consensus on the statistic to be used in evaluating the fit, but in most cases a simple measure such as the mean absolute deviation (MAD) or the percentage absolute deviation (PAD) have been used.

The testing of the model was done by imposing all of the relevant policies which were current in 1988, specifically the marketing and pricing regime for each product, credit policy and other on-farm policies, in order to see how well it simulated the existing (1988) situation. The better the current situation is represented by the model, the more reliable the model. The values generated by the model correspond fairly well with the actual values for the Western Cape as a whole, although this is not necessarily true for the 13 sub-regions.[3] If a deviation of 15 per cent is deemed acceptable as a general rule of thumb (as suggested by Hazell and Norton, 1986), all the generated production quantities for the Western Cape are within this limit. A PAD of 8.19 per cent across all commodities for the Western Cape (as a whole) is obtained, which is adequate for this type of model.

4. RESULTS

4.1 Introduction

Two different types of water policy scenarios were modelled to demonstrate the working of the model, and to illustrate the effects of policy changes on production, price and welfare of the major (interest) groups involved in the analysis. These policy scenarios are (1) lower availability of water to the farm sector as a whole; and (2) increases in water tariffs.

The selected key variables which are monitored to determine the effects of policy changes include the physical change in output (area under production for each of the commodities and livestock numbers); commodity prices; employment; and changes in producer welfare, consumer welfare and total (social) welfare. The values from the base scenario are used as the basis for comparison in each case. The information provided by the base scenario simulation was subsequently used to compare the different policy changes as specified in the scenarios mentioned above. It is important to emphasise that all other variables, for example transport costs, exchange rates, international prices and interest rates, stay the same for each scenario.[4]

4.2 Assumptions

The results obtained with the different policy simulations are often a function of the set of assumptions that underpin the analysis. Therefore, it is necessary to explicitly state some of the most important assumptions which impact on the subsequent results. Also, the direction of change is often much more important than the actual magnitude of the results obtained. For this reason less emphasis

[3] *In some of the individual sub-regions, relatively small quantities of some specific commodities are produced (see Table 3). In these areas, the model predicts a relatively large deviation (increase or decrease) of up to 75 per cent of the actual production, but in absolute terms these variations are small and insignificant. Where a specific commodity is important in a region, the model predicts both the relative and absolute production levels fairly accurately.*

[4] *This restrictive ceteris paribus assumption allows for evaluation of the effects of the specific scenario in relative isolation.*

should be placed on the actual results than on the direction of change, while the assumptions which underpin the analysis should be considered together with the analysis of the results.

The most limiting factors in the analysis are as follows: (1) only the farm sector is modelled, with no attention given to changes in the farm input sector (credit aside); (2) there is no scope for changing input mixes of commodities in reaction to changes in output prices -- the assumed underlying technologies and market demand guide the whole system; (3) income changes and its effects on demand are not taken into account; (4) specific transport costs, exchange rates and international prices underlie the analysis; and (5) changes are not shown in a dynamic manner, but as final results.

4.3 Results of policy changes

Scenario A: Lower availability of water to the farm sector as a whole

In the first scenario, the total availability of water to the farm sector is reduced by 10, 30 and 50 per cent of current use, respectively. This scenario allows for the full complementarity and supplementarity that exists with respect to water use between the different commodities within the different production sub-sectors. The production of the different commodities will be affected in different ways when water availability becomes increasingly limited, and the available water is transferred to the most profitable commodities. It was assumed that water cannot be transferred between the ten relatively homogeneous sub-regions within the model, but that each region will be subjected to the same decrease in water availability. Table 1 provides a summary of the results.

From the table it is clear that the production of field crops and intensive livestock products will increase with lower water availability, while vegetable, fruit and extensive livestock production will decrease. The direction of change stays the same regardless of the level of the constraint on water availability, but as expected, the magnitude of change increases the less water is available. This seemingly counter-intuitive result has important consequences for total welfare and for the level of employment in Western Cape agriculture.

The sequence of the argument starts with the availability of water. In the first example, the stock of water is decreased by 10 per cent. The first reaction of the model is to reallocate water to its highest and best use. However, because water is less available, some amounts of other resources such as land are left idle. So, for example, one would expect that water will be reallocated from wheat under irrigation to higher value fruit. The land that was being used for the less valued irrigation crops will be left idle, as there is not enough water for it to be kept under irrigation. It is then reallocated to uses which do not require water, such as dryland field crop production and extensive livestock production.

Table 1: Effects of different scenarios of decreased water availability to the farm sector

Measure	Item	Deviation of simulation results from base values (%)		
		10%	30%	50%
Production	Production of crops (ton):			
	Field crops:	+	+	+
	Vegetables	-	-	-
	Fruit:	-	-	-
	Number of livestock:			
	-Extensive	-	-	-
	-Intensive	+	+	+
Prices	Field crops:	-	-	-
	Vegetables	+	+	+
	Fruit:	+	+	+
	Livestock:			
	- Extensive	-	-	-
	- Intensive	+	+	+
Welfare	Producers	-4.72	-21.54	-35.60
	Consumers	-2.48	-8.49	-14.73
	Total	-2.64	-10.25	-17.87
Employment	Farm employment	-3.56	-13.40	-31.20

Table 2 also shows the details of this result. All the sectors that are water-intensive (vegetables, fruit, dairy, angoras, pigs and chickens) experience a drop in output as water is allocated away from their use. The freed resources are allocated to wheat, barley, oats, beef cattle, and wool and non-wool sheep. These increases and decreases are reflected in the changes in commodity prices in the lower half of the table. So, for example, an increase in field crop production is reflected in a lower price, while a decrease in fruit production results in a higher price.

It is important to note, as stated previously, that these changes in the physical volume of production and in prices are the net result of a chain of shifts in supply and demand that take place as a result of the changing availability of water.

The effect on welfare and employment are fairly predictable, and disastrous.

Producers as a group lose, because production shifts away from high value crops and livestock products to extensive field and livestock sectors. Consumers as a group lose, even though they are paying less for basic foodstuffs. The total

Table 2: Effects of different scenarios of increased irrigation tariffs

Measure	Item	Deviation of simulation results from base values (%)	
		100% increase	200% increase
Production	Production of crops (ton):		
	Field crops	0	+
	Vegetables	0	-
	Fruit		
	- oranges	0	0
	- apples	0	+
	- pears	0	+
	- peaches	0	0
	- table grapes	0	0
	- wine grapes	0	0
	Number of livestock:		
	- Extensive	0	+
	- Intensive	0	-
Prices	Field crops:	0	-
	Vegetables	0	+
	Fruit:		
	- oranges	0	0
	- apples	0	-
	- pears	0	-
	- peaches	0	0
	- table grapes	0	0
	- wine grapes	0	0
	Livestock:		
	- Extensive	0	-
	- Intensive	0	+
Welfare	Producers	-3.8	-8.4
	Consumers	0	+0.5
	Total	-0.4	-0.7
Employment	Farm employment	0	+4.3

welfare of the Western Cape, which is the sum of the producer and the consumer surplus, therefore also decreases. Finally, as production shifts from intensive to extensive industries, the labour intensity of agriculture also declines, as can be seen by the decline in employment. This discriminates against the poor, so the conclusion can be drawn that the net effect of the changes is regressive in terms of income distribution.

In summary, any decrease in the total availability of water will have a negative overall effect on the Western Cape economy, and it will penalise the poor more strongly than other groups through the decline in job opportunities. These effects grow more than proportionally as the limitation on available water becomes tighter.

These consequences could, of course be mitigated if the restriction on available water were to be matched by reactions such as a more efficient use of available water. This could be accomplished through lower wastage (better water management) or better technology.

Scenario B: Increased water tariffs

Scenario B refers to a situation where water tariffs are increased in two steps: (1) tariffs that are lower than the most expensive tariff in each sub-region are increased to the highest level. This includes attaching a tariff to water that is not tariffied; and (2) these tariffs are then doubled or tripled, depending on the specific scenario. Table 6 provides the results.

From the table it is clear that changes in water tariffs have a very different effect to limitations in total water availability. When all water throughout the province is priced at the level of the highest existing tariff, and all tariffs are then doubled, there is little economy-wide effect on output, prices, welfare or employment other than a small reduction in producer surplus because of the need to pay for more water. However, this small average reduction in producer profits falls entirely on irrigation farmers, and is equivalent to much larger reduction in their profits. Despite this reduction, the model predicts that producers will absorb this cost increase, as there are no discernible output and price effects.

There is, however, some evidence of a reaction by farmers when this procedure is repeated with a tripling of the highest tariff. The changes are also not quite the same as in the case of the lower availability of water. In this case, field crop production and extensive livestock production also increases, while vegetable and intensive livestock output decreases. However, fruit production, and specifically apple and pear production, increases. Once again, the price changes reflect these changes in output.

The reasoning for these changes starts with the effect of the higher tariff. Water is switched from lower to higher value irrigation crops (in this case apples and pears), while some land is taken out of irrigation production because the higher tariff increases the cost of irrigation to the extent that it is no longer profitable.

Producers as a group lose from these changes in the pattern of output and prices, while consumer welfare changes only slightly. There is a relatively larger increase in employment, most of which can be ascribed to the increased apple and pear production, as it is more labour intensive than the other sectors that show output increases.

5. CONCLUSIONS

The conclusions which are drawn from this analysis, subject to the numerous assumptions made, are as follows:

- Both scenarios will lead to a relative shift away from intensive production sectors in agriculture towards more extensive sectors. In the case of a large increase in water tariffs, however, apple and pear production will increase, although there is no effect on the production of other fruit.

- In both cases the producer welfare decreases. However, a large water tariff increase is required before it has any effect on producer welfare. It seems as if farmers are able to absorb tariff increases with relative ease.

- While the effect of tariff increases is small, the proportionate effect on irrigation farmers will be larger, even though they absorb these increases. With a very large increase in tariffs, some farmers will switch out of irrigation farming.

- The effect on consumer welfare is, in both cases, smaller than the effect on producer welfare. When the amount of water available is restricted, consumer welfare decreases.

- In the case of a restriction on water availability, total employment in the farm sector decreases as producers switch to a more extensive production pattern. The total decline in welfare, therefore, falls disproportionately on the poor in the province.

- In the case of an increase in tariffs, the effect on consumer surplus falls disproportionately on the poor, but is mitigated by an increase in employment.

- In the long run either of these two changes have a negative effect on agriculture, as they represent a shift away from industries where Western Cape producers have a competitive advantage towards industries where no such advantage exists at present.

- In both cases the spill-over effects on the rest of the Western Cape economy can be deduced. Broadly, a decline in water availability will lead to rural decline in the province. Farmers will earn less, there will be fewer job opportunities in farming, and less intensive production will lead to weaker links to the agro-industrial sector, meaning less jobs and less disposable income in rural areas. In the case of increases in water tariffs, these effects are much smaller, and are mitigated by an increase in apple and pear production when tariffs are increased substantially.

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