WATER MARKETS AN ALTERNATIVE FOR CENTRAL WATER ALLOCATION?

D.B. Louw[1] and H.D. van Schalkwyk[2]

South Africa is entering a whole new era in water management. In the face of efforts to curtail runaway government spending and protect the environment, water institutions must foster the conservation and efficient allocation of existing supplies. They must also take water's growing recreational and environmental value into account. The crucial question is, can the current water institutions meet today's requirements? Despite the resulting inefficiency and waste, traditional resource economists continue to identify taxes, regulations, subsidies, and governmental allocation as solutions to today's water problems. Internationally, there is enough evidence to prove that central allocation with almost any resource gave rise to gross inefficiency. The main reason is the distortions on the value placed on resources within such a centralised planning environment. Resources are either valued to high or to low. What is the value of freshwater and how can water be allocated in such a way as to reflect the scarcity value of water? A non-linear spatial equilibrium model was developed to simulate the impact of a potential water market in the Upper-Berg River: Western Cape. This paper explores water markets as an alternative to central water allocation decisions

1. INTRODUCTION

In spite of the vital life-support service which water renders to the planet, historically water was seldom considered to have economic value. Water was believed to be in abundance, which were available to supply the socio-economic demands of the time. This situation caused water to be a non-tradable commodity and therefore a free good. However, the continued growth in demand for water from all user sectors has changed this believes considerably. Today water is considered as an economic good and a valuable asset. In 1992 this principle was adapted at the Water and Environment Conference in Dublin. Although still not well understood or well defined, the concept was already manifested in many regions of the world in the form of privatisation of water supplies, the emergence of water markets, and the proliferation of bottled drinking water. This marked the end of the era of water as a free good. Many current problems in water allocation policy are

1 *Chair in International Agricultural Marketing and Development, Department of Agricultural Economics, University of the Orange Free State, P O Box 339, Bloemfontein 9300.*

2 *Department of Agricultural Economics, University of the Orange Free State, P O Box 339, Bloemfontein 9300.*

due to a failure to recognise the connection between institutional settings, states of technology and the hydrology of water systems. These problems will only grow more in future until these connections are specifically acknowledged and addressed in water policy decisions (Whittlesey & Huffaker, 1995).

The new South African Water Act provides the framework for water markets in South Africa. For the first time in South African history water legislation makes provision for water trading as an option for water allocation. However, preferences are still given to administrative price setting for water resources. Whilst the National Water Act mentions water markets as a possible alternative to allocate water it is very unclear with regard to the legal transfer of water use licences. This creates uncertainty. Furthermore, the extent of bureaucratic control and regulation of water trading in the new water legislation creates highly restrictive conditions for voluntary transfers between willing buyers and sellers (Armitage, 1999). Even if water markets are introduced the above factors will increase transaction costs and will undermine the working of an effective water market. It should be clear from the above that the water allocation debate in South Africa is far from over.

This paper attempts to contribute to the debate by investigating the possible impact of a water market. A non-linear spatial equilibrium model is used to quantify the value of water for different water users and to explore guidelines for the working of a water market in the Upper-Berg River in the Western Cape. The Upper-Berg River is one of the rivers in South Africa where almost all possible problems which might be associated with a water market exists and is therefore an excellent area to use as a case study.

2. BASIC DESCRIPTION OF THE MODEL

The model specifications coincide largely with those made by Takayama and Judge (1971), Batterham and MacAulay (1994), and Eigenraam (1996). For the sake of brevity the full model is not included in the text, a complete description of the model can however be obtained from the authors. Trade occurs in the model where excess supply (ES) equates excess demand (ED). The maximum volume of a commodity that can be supplied by a system if the commodity price was not a limiting factor is limited by the fixed resource restrictions. The excess supply is the difference between this maximum and the volume being produced at the present price. The excess demand can be defined in similar fashion. Excess demand for water is for example the volume of water that can be profitably used but which is in excess of the water currently available. The buyer with the highest price intercept will be the excess demand buyer. Similarly the seller, who can supply at a lower price, will determine excess supply. The direction of trade will be from the lower priced person/business to the higher priced person/business as long as the price difference between the two regions is greater than the transport and transaction costs.

The Upper-Berg River water allocation model consists of seven irrigation regions; Berg River one, two and three, Suid-Agter Paarl, Noord-Agter Paarl, Perdeberg and Riebeek-Kasteel. The irrigation regions are represented by 18 typical farms, which were constructed with survey data. In the model the typical farms represents the excess supply and excess demand for irrigation water from each of the regions. The urban water demand sector is represented by a single demand function for industrial, household and other non-agricultural use. There is no elasticity estimates available for the urban sector in the Cape Metropolis. An average figure from various studies (Hanke & De Mare, 1982) was assumed for the urban demand function. Although it will be more accurate to model the urban user sectors separately, this will increase model size and complexity substantially. The model makes provision for temporary as well as permanent water trade between all the user sectors. The Cape Town Water Undertaking (CMC) supplies more than 90 percent of all the urban water to the Cape Metropolis, Stellenbosch, Paarl and Wellington. All the present water supply sources are incorporated in the model. However, only the Theewaterskloof dam water is available for agriculture as well as urban water and therefore available for trade. Also included in the model are future possibilities for water augmentation schemes such as desalinating of seawater and recycling of sewerage water. The model calculates the value of water for water users who trades as well as those not trading. Water prices for the urban sectors are determined endogenously. Ecological and reserve demands are met through a fixed variable forced into the solution by a fixed ecological and reserve demand per month.

The model is written in GAMS (General Algebraic Modelling System) and solved through the MINOS 5 solver. A solution to the model consists of the equilibrium supply and demand of water quantities for different water users and regions and transhipment quantities of water under various water trade scenarios. Thus, the model can reveal the value attached to water use rights by the different water users and irrigation regions, changing agricultural and urban water demand and supply under various scenarios and policy options. The model is complicated by the fact that it has to include the supply infrastructure and the demand sectors as close as possible. The model comprises around 7146 variables and 2936 equations. The objective function is constructed in such a way as to minimise water use of the urban as well as agricultural sector. The urban water price includes the present purification cost and operation and maintenance cost for purified water. Due to the static nature of the model present value methods were used to accommodate long-term crops. All prices in the model are for a discounted stream of cash inflows and outflows over a twenty-year period. Base prices are 1999 prices discounted with an interest rate of 13 percent (based on the median Commercial Bank 12 month fixed deposit rate of 10.75 percent plus a 2.25 percent risk rate).

4. DATA USED

Agricultural data was obtained through a farm survey conducted among 70 farmers in the Upper-Berg River, from the database of the Deciduous Fruit Producers Trust and from the KWV. Crop budgets were compiled with the Micro-Combud system developed by the Department of Agriculture: Western Cape. The urban data was obtained from various sources, including: Western Cape System Analysis reports (1989-1996) and the Cape Metropolitan Council Annual report of the City Engineer (1980-1999). There is no example of a relative free water market in South Africa and the transaction costs that will apply in such a market. It was assumed that for a high transaction cost scenario the transaction cost for permanent water trade would at least not be higher than the cost incurred during the old water law regime. In the Orange River where water transfers were common since the late 1980's, the cost varied between R2000 and R6000 per farm of 30 ha with an allocation of 15000 m^3 per ha. This cost did not provide for electricity and other irrigation infrastructure as well as brokers fees (Armitage, 1999). Although there is no similar published transaction cost figures available for the Berg River, the farm survey revealed that farmers payed about 6 cent per m^3 of water for permanent water transfers. Informal temporary water transfers between farmers are common in the Berg River. According to the survey results there is no transaction costs as most of the transfers is "friendly" agreements between farmers. However, for the purpose of this paper a relative high permanent (6 cent per m^3) and temporary (3 cent per m^3) transaction cost are assumed. The high transaction cost is then reduced with 50 percent in order to demonstrate the impact of lower transaction cost. The agricultural land and water use as calculated by the model are aggregated with aggregation factors in order to simulate the total agricultural resource use for the Upper-Berg River.

Competition between the urban and agricultural sector is only applicable with regard to the Theewaterskloofdam as the other sources belongs to the CMC from which agriculture receives no allocation. Trade in this regard is therefore limited only to the Theewaterskloofdam. Other water sources for the urban sector include the Table Mountain dams, Steenbras dam, Wemmershoek dam, Voëlvlei dam and the aquifers at Atlantis. The Palmiet River water transfer scheme only came into operation in March 2000 and will supplement the urban water supply with 31 million m^3 of water per annum.

5. SCENARIOS

The analysis comprises of three issues:

- A no trade versus trade scenario with present water use and with relaxed constraints on present water and land use.
- Water restriction scenarios under free trade conditions.
- Projected urban demand scenarios under free trade, free land use conditions.

The different scenarios are contrasted principally to a base scenario. The following scenarios were investigated:

A. Trade versus no trade

1) Base scenario: present agricultural land and water use and present urban water use.

2) Free trade scenario: present agricultural land and water use and present urban water use.

3) Free trade scenario: relaxed restriction on agricultural land use (40 percent deviation) and urban use. The total irrigation and dry land area available are increased with 10 percent for the upper reaches of the Berg River and 20 percent for the lower reaches. A relaxed urban demand but ensuring that at least 70 percent of the base urban demand is satisfied. Relative high transaction costs.

4) The same as scenario 3 but transaction costs are reduced with 50 percent.

B. Water restrictions

1) Base scenario: same as A.4.

2) 10 percent restriction on all water allocations.

3) 20 percent restriction on all water allocations.

4) 30 percent restriction on all water allocations.

5) 40 percent restriction on all water allocations.

C. Increase in the urban water demand

It was assumed that the urban demand for the Cape Metropolis (CM) would increase with 4 percent per annum over the next 20 years. The base water demand was therefore adapted with every scenario to incorporate this increase. It was also assumed that there is no restriction on land use and that farmers can adapt to the scarcity of water over the medium to long term.

1) Base scenario: same as A.4 but no restrictions on land use structures.

2) 2005 projected urban demand: 20 percent increase from base.

3) 2010 projected urban demand: 40 percent increase on base.

4) 2015 projected urban demand: 60 percent increase on base.

5) 2020 projected urban demand: 80 percent increase on base.

It must be noted that the model only provides for a summer demand price (September to March) and a winter demand price (April to August). Further development of the model will also provide for a sliding scale price structure such as the one that is currently being constructed by the Cape Metropolitan Council (CMC).

6. RESULTS

Due to the limitation on space no trans-shipment matrices for the water transfers between the irrigation regions (typical farms) are presented. A complete report is available from the authors. The results shown in this paper only show the transfers between agriculture and urban use. The values calculated for water only shows the median, maximum and minimum values for each of the scenarios. The results are shown in Table 1.

Table 1: Simulated results of different water trade scenarios

	Scenarios													
	Trade versus no trade				Water restriction scenarios					Urban demand scenarios				
	A.1	A.2	A.3	A.4	B.1	B.2	B.3	B.4	B.5	C.1	C.2	C.3	C.4	C.5
Objective function(mill)	5387	5415	5596	5598	5598	5564	5530	5483	5343	5772	6803	8025	9369	10005
Irrigated (ha x1000)														
Long term crops	14.65	14.65	14.70	14.48	14.48	14.48	14.48	13.57	12.26	15.44	15.44	12.71	9.63	8.87
Short term crops	0.71	0.71	0.64	0.64	0.64	0.64	0.64	0.64	0.57	0.10	0.10	0.06	0.01	0.01
Total irrigation ha	15.36	15.36	15.35	15.13	15.13	15.13	15.13	14.21	12.82	15.54	15.54	12.78	9.64	8.89
Irrigation land value (Rand)	0.0	0.0	27.1	25.9	25.9	25.9	25.9	20.1	4.4	108.9	108.9	91.9	39.3	17.4
Dryland ha	15.53	15.53	17.51	17.51	17.51	17.51	17.51	17.51	17.51	25.66	25.66	25.66	25.66	25.66
Dryland value (Rand)	0.00	0.00	0.33	0.33	0.33	0.33	0.33	0.33	0.33	36.05	36.05	35.97	35.55	35.13
Difference in value	0.0	0.0	26.8	25.6	25.6	25.5	25.5	19.8	4.1	72.8	72.8	56.0	3.7	-17.7
Water use (Agriculture)-Mill m^3														
Total water allocated	62	62	62	62	62	55	49	43	37	62	62	62	62	62
Allocation water bought	42	55	55	55	55	50	44	39	37	55	55	55	62	62
Dam water	29	29	29	29	29	29	29	29	29	29	29	29	29	29
Permanent trade	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tempory trade	0.0	3.7	4.5	4.0	4.0	4.5	5.7	5.1	0.7	8.4	8.4	5.2	0.9	0.7
Total m^3 used per annum	70.8	70.2	71.2	70.0	70.0	70.5	71.7	66.7	54.6	77.0	77.0	61.8	41.7	38.2
Water use (Urban)-Mill m3														
Total allocation - Theewaters	183	183	183	183	183	165	146	128	110	183	183	183	183	183
Allocation bought	162	144	85	84	84	107	129	128	110	87	142	183	183	183
Permanent trade	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tempory trade	0.0	17.9	17.7	18.3	18.3	12.8	7.3	6.2	12.3	15.8	15.8	27.8	50.1	53.4
Other dams	171	171	171	171	171	154	138	135	123	171	171	177	202	202
Possible sources	0	0	0	0	0	0	0	0	0	0	0	0	0	27
Total cubm used-all sources	333	333	274	274	274	274	274	270	245	274	329	388	435	466
Total trade (urban plus agric)	0.0	21.6	22.2	22.3	22.3	17.3	13.0	11.3	13.0	24.1	24.1	33.0	51.0	54.1

Table 1 (continued)

	Scenarios													
	Trade versus no trade				Water restriction scenarios					Urban demand scenarios				
	A.1	A.2	A.3	A.4	B.1	B.2	B.3	B.4	B.5	C.1	C.2	C.3	C.4	C.5
Average urban water price	16.3	16.3	19.9	19.9	19.9	19.9	19.9	20.2	21.7	19.9	19.9	20.2	21.3	21.7
Values (Cent per m³)														
Present allocation														
Urban	1.92	1.92	1.92	1.92	1.92	1.92	1.92	2.43	6.46	1.92	1.92	2.43	5.23	8.00
Median agricultural value	0.00	1.37	1.37	1.47	1.47	1.47	1.47	1.98	6.01	1.47	1.47	1.98	4.78	7.55
Maximum value	0.45	1.37	1.40	1.49	1.49	1.49	1.49	2.00	6.04	1.50	1.50	2.01	4.81	7.58
Minimum value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.68	0.00	0.00	0.00	2.45	5.22
Value of trade water														
Urban	0	1.92	1.92	1.92	1.92	1.92	1.92	2.43	6.46	1.92	1.92	2.43	5.23	8.00
Median agricultural value	0	1.73	1.73	1.82	1.82	1.82	1.82	2.33	6.36	1.82	1.82	2.33	5.14	7.90
Maximum value	0	1.82	1.82	1.87	1.87	1.87	1.87	2.38	6.41	1.87	1.87	2.38	5.18	7.95
Minimum value	0	1.72	1.72	1.81	1.81	1.81	1.81	2.32	6.36	1.81	1.81	2.32	5.13	7.89
Value of other sources														
Table mountain dams	1.92	1.92	1.92	1.92	1.92	1.92	1.92	2.43	6.46	1.92	1.92	2.43	5.23	8.00
Steenbras dam	1.92	1.92	1.92	1.92	1.92	1.92	1.92	2.43	6.46	1.92	1.92	2.43	5.23	8.00
Wemmershoek dam	1.92	1.92	1.92	1.92	1.92	1.92	1.92	2.43	6.46	1.92	1.92	2.43	5.23	8.00
Voelvlei dam	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.64	5.67	1.13	1.13	1.64	4.44	7.21
Palmiet transfer scheme	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.03	0.00	0.00	0.00	2.80	5.57
Atlantis Aquifers	1.92	1.92	1.92	1.92	1.92	1.92	1.92	2.43	6.46	1.92	1.92	2.43	5.23	8.00
Theewaterskloof dam	1.92	1.92	1.92	1.92	1.92	1.92	1.92	2.43	6.46	1.92	1.92	2.43	5.23	8.00

6.1 Trade versus no trade scenario

It is clear from Table 1 that administrative allocation of water leads to incorrect valuation of the value of water. If free trade is allowed with no slack activity on the resource use, there is not much of a difference in the valuation of the water resource although some trade takes place. As soon as a water market is introduced and it is possible for the users to adopt other water use patterns, trade takes place to higher value uses and the value of water increases because users take the opportunity cost of the various uses into account when they use water. The median, presents the allocation value and it increases form zero in the base to R1.37 and R1.47 per m^3 at the higher (A.3) and lower transaction cost (A.4) scenarios. The median value of transferable rights increase from R1.37 in scenario A.3 (high transaction costs) to R1.82 (low transaction costs). It is clear what the impact of transaction cost is. If transaction costs is high the advantages of trade is eroded away and therefore reduces the volume of water being traded. The total trade (urban plus agricultural trade) are reduced from 22.3 to 22.2 million m^3 of water if transaction costs increase with 50 percent. It is also clear that urban water consumption reduces with 59 million m^3 (333 to 274 million m^3) when the average urban water price increases from R16.3 to R19.9 per m^3 (22 %) in reaction to the market signals. The analysis also clearly indicates that water trade shifts to some extent from between irrigation users in the high transaction cost scenario towards urban trade in the low transaction cost scenario. The urban sector values present water use rights at R1.92 per m^3.

6.2 Water restriction scenarios

Scenario B.2 to B.5 clearly indicates how the value of water use rights adapt to the scarcity of the resource and how trade can solve some of the problems during decreasing water supplies. As the restrictions increase, water is valued higher by all sectors. The total amount of irrigated land decreases from approximately 15000 ha (B.1) to about 12800 ha (B.5) when only 40 percent of the allocated water is available. It is also clear that the productive value of irrigation land as indicated by the shadow price declines form about R25900 (B.1) to about R4 400 (B.5). The reason why major adjustments in the agricultural sector only begin when the allocated water resource declines with 30 percent is that the urban sector only starts to use there full allocation from Theewaterskloofdam when water is restricted with 30 percent. The median agricultural value on the present agricultural allocation increases from R1.47 to R6.01 per m^3 of water and the value of trade rights from R1.82 to R6.36 rand per m^3. Trade of water rights for all users shows an initial increase when restrictions are implemented at a lower level. As the restrictions increase there is a scarcity in water available for trade and a rapid decrease takes place in scenario B.5 when only 40 percent of the allocated water is available. It is also clear that as the urban sector uses all available supplies, the last option is the desalination of seawater or recycling of sewage water. These options are however 4 to 10 times more expensive than other surface water sources and there is a more than 100 percent increase in the valuation of all the available water sources. It is however important to note that it will not be possible for the agricultural sector to make quick adjustments during water shortage years. These scenarios are therefore not realistic but attempts to illustrate the working of a water market. However, during years of shortage farmers will be able to trade water temporally to the urban sector and other higher valued users. Water markets will make a major contribution to alleviate the shortage in the sense that marginal or unproductive water users will release water to other users.

6.3 Urban demand increase

Scenario C.1 to C.5 shows the impact of projected increases in water demand for the Cape metropolis for 2005 to 2020. It was assumed that the irrigation sector could make major structural adjustments during this period. However, it is important to note that the present model does not account for the important multiplier effects of the agricultural sector. If the multiplier effects are incorporated costs might proof to be to high and a better option from a welfare point of view might then be to rather desalinate seawater or recycle sewage water. It is clear from the analysis that if multiplier effects are not taken into account there will be a substantial transfer of water from agricultural use to urban use when the opportunity cost for the agricultural sector becomes to high. This is especially evident during 2010 to 2020 when the total area under irrigation declines from about 15 500 ha in the base analysis to round about 12 780 (C.3) and 8 890 (C.5). There is a rapid decline in the value of irrigation land and an increase in the value of dry land. Agricultural land use will shift to dry land use and the export earnings of the Western Cape will decline rapidly. This will lead to major social problems as unemployment will increase and secondary industries will start to experience the impact in the reduction in agricultural output. The average urban water price increases from a relative price of R19.9 to R21.7 per m^3 (present value over a twenty year horizon).

7. CONCLUSION

Although the model can still be improved with regard to the accommodation of various aspects, the model clearly indicates that water allocation through an efficient water market can make a major contribution to alleviate water shortages. The most important mechanism in a water market is that allocation of water is value driven. The user with the highest value (willing buyer) is enabled to buy water form users who attach a lower value to water (willing seller). Only temporary trade took place in the analysis of the scenarios. The reason for this is that the model is static and there is not enough information for the model to make a proper judgement between the differences of the two alternatives. Further refining of the model will attempt to address this problem.

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