Water Price of Taiwan

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I. Preface

In Taiwan, the shortage of water has become a common event in recent years. However, the government plan to develop water resource was protested or even stopped by the public with environmental concern. A major reason of over use of the water resource is the artificial low price cause by the government subsidy. For instance, consumers don't cherish water resource exhibited in wasted use of treated water. Industries not only use cheap treated water but also expend freely extract a large quantity groundwater. Therefore, the high polluting and energy-intensive industries expand very rapidly. As the result, we have to burden a got a lot of social cost in ground level subsidence, salinification of groundwater and invasion of sea. Our natural environment is damaged badly and the society has to pay a lot for recovering or repair. Water right system is not implemented properly to protect the overuse of the resource. To remedy the situation, Taiwan must develop or implement a policy, including the pricing, water right, usage of water resource and pollution control.

Water resource is sort of renewable resources in most instances. When people expend water over the limitation, cost will rise greatly. If the price can cover the cost, the consumption will be arrested. According to economic principle, market mechanism will lead suppliers and consumers to reach the highest efficiency of water resource. Market mechanism is the price. This research is based on considering

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the supply and demand side of water resource simultaneously by using a grey programming as a tool to build a balancing model. The model solution is to provide source guidelines for the development of an implementable plan to manage water resource in Taiwan.

II. Research Method

1. Based on secondary information contained in literature of government, we estimate a range of cost for various kinds of water source, such as reservoir, river, groundwater, and desalinization, etc. The estimation of the limits on these sources is based on the statistics of water resource by the Water Resource Bureau's yearly data. We get a total (weighted) cost by adding all the numbers that multiplying the cost of every water source and their supply together.
2. Demand of water resource: On the assumption that the linear demand equation of water resource is P = a - b * Q, we get the demand elasticity: $\varepsilon = -(1/b) * (P/Q)$ pertaining to current price, quantity and the elasticity of all consumers,
3. Equilibrium price: We get the net benefit as goal function as show in Eq.1 by subtracting supplying cost that was estimated in Step 1 from the revenue that was estimated in Step 2 (the area below the demand). The equilibrium price is reached when the benefit is maximized and the marginal cost is equal to the marginal benefit. The sum of the supply from every water source should at least meet the total demand quantity Q_t as Eq.2. The quantity of every water source should be restricted by its upper limit as Eq.3 and must be positive as Eq.4. Following is the equation of grey coefficient (Eq.5.6.7.8).

$$F = Max\left\{\left[\int_0^{Q_t}((\otimes a)-(\otimes b)Q)dQ\right]-\left[\sum_{i=1}^{n}((\otimes C_i)\times Q_i)\right]\right\}, \forall i \ni N$$

$$= Max\left\{\left[(\otimes a)Q_t - 1/2(\otimes b)Q_t^2\right]-\left[\sum_{i=1}^{n}((\otimes C_i)\times Q_i)\right]\right\}, \forall i \ni N ....Eq.1$$

$$\sum_{i=1}^{n} Q_i = Q_t, \forall i \ni N ....Eq.2$$

$$Q_i \le (\otimes L_i), i = 1,2,...,n ....Eq.3$$

$$Q_i \ge 0, i = 1,2,...,n ....Eq.4$$

$$(\otimes C_i) = \underline{C_i} + \sim(\overline{C_i} - \underline{C_i}) ....Eq.5$$

$$(\otimes L_i) = \underline{L_i} + \quad (\overline{L_i} - \underline{L_i}) ....Eq.6$$

$$(\otimes a) = \underline{a} + ¥(\overline{a} - \underline{a}) ....Eq.7$$

$$(\otimes b) = \underline{b} + {}^{-}(\overline{b} - \underline{b}) ....Eq.8$$

F is the benefit; $(\otimes C_i)$ is the cost grey number of every water source; $(\otimes L_i)$ is the restricted quantity of every water source; Q_i is the decision variable of water supply. If we set the reliability as 0.7, we can get the Q_i, Q_t and p, namely the quantity of water sources, total water supply and the water price under equilibrium.

4. Comparing the price with that of other nations: Compare the result of Step 3 with other countries' price and precipitation per capita per year.

III. Model Data and Result

Following is the table of water source's cost and supply.

Table 1: Water sources' cost and supply limit

Kinds of water sources	Cost $\otimes C_i$ (NT$/ton)	limit quantity $\otimes L_i$ (million tons)
Reservoir-1	1~6	(3900~4200)-11*T
Reservoir-2	11~23	2334~3055
River	2~6	5313~7047
Groundwater	1~2	1800~2200

Pond in farm	7~12	67~90
Desalinization-1	21~27	277~347
Desalinization-2	27~49	1385~1735
Recycled water	60~100	1749~2624
Irrigation return flow	8~10	2635~3953
Rainwater collection	48~52	255~510

* "T" stands for time (year). If we set the object for 2001, then t is 4.

With data of Table 1 supply-demand model solving gives the result as show in Table 2.

Table 2: Result of equilibrium for water sources supply-demand

Sources	Result（million tons）
Reservoir-1	4113<Q1<4200
Reservoir-2	0<Q2<2145
River	6544<Q3<7047
Groundwater	2084<Q4<2200
Pond in farm	83<Q5<2200
Desalinization-1	Q6=0
Desalinization-2	Q7=0
Recycled water	Q8=0
Irrigation return flow	3571<Q9<3953
Rainwater collection	Q10=0
Quantity	16395<Qt<19635
Price	11<P<13.8

The result shows that the quantity demanded will be between 16395 and 19635 million tons/year and with a charge between NT$11 and 14 per ton to raw water. It appears that there are no needs for new resources like desalinization, recycling and rainwater collection.

Table 3 is the existing water price of other countries and precipitation per capita.

Table 3: Water prices of other countries and precipitation per capita

Country	Population (10^4)	Area ($10^3 km^2$)	Yearly precipitation (mm/year)	Precipitation per capita (m^3/capita year)	Average price (NT$/$m^3$)
Canada	2960.6	9976	522	175892	
New Zealand	359.2	269	2010	150526	16
China	12714	9597	660	49819	
America	26309	9363	760	27047	
Philippines	7027	299	2360	10042	
Spain	3960	496	600	7515	28-48
Rumania	2270	238	700	7339	
France	5826.5	551	750	7093	79
Turkey	7300	779.5	508	5424	20
Japan	12556	377.8	1749	5263	42-46
Italy	5728	301	1000	5255	
Denmark	518	43.1	610	5075	128
Britain	5857	241	1064	4378	20
Taiwan	2135.7	36	2510	4231	7.7-9
India	93000	3230	1170	4064	
Belgium	1002	30.5	890	2709	65
Germany	8120	248	803	2453	
Netherlands	1504	41.5	760	2097	50-53
Egypt	6060	1001	65	1074	
Singapore	310	0.647	2550	532	17
Hong Kong	631	1.072	2225	378	15-36

In Taiwan, the water sources for each person is less than most other countries, but the price in our country is the lowest. If we charge NT$10 per ton to raw water above the treatment, the price should be raised to NT$21~24. This result will be closer to the price in Britain, which has similar endowment condition of water resources, and the price will be reasonable.

IV. Conclusion

Discussion:

1. According to equilibrium, rivers and reservoir-1 (reservoir built in the previous stage) must be used thoroughly. Thus, conservation of rivers and reservoirs is an emergency. In addition to dredging reservoirs, we should improve the quality of water. The using of water in reservoir-2 (reservoir just finished and planned to build) is free; this means after we raise the price of water, we even don't need to build new reservoirs. To make sure that groundwater has enough hydraulic gradient to the ocean; it can only be used about 2048 to 2200 million tons. This infers an enormous discrepancy exists between the present situation of using 7000 million tons and the analytical result. The using of groundwater should be managed and restricted more effectively.
2. Because of the limitation of grey programming, the result of programming is closer to the bottom of cost range and the top of restricted range. Water price would be lower than the normative price.
3. Water supply will be changed by natural condition, technology and management (such as silting, leaking, etc.) with time.
4. Because the estimating of environmental cost is too complicated, this is out of consideration in this research. The result does not reflect the environmental cost completely.
5. This research is based on price of raw water. The price of the result is a

reference point for policy development. The consumers or industries must give further consideration to the need for water quality.

Suggestion:

1. The policy of reasonable water price made by Water Resource Bureau should be practiced right away to stop the wasting of water resource. Setting "standard in basic water quantity for living", people who use water more than the standard have to pay more money, which will be raised to $21~24/m^{3} by degrees.
2. Establish the system of water rights quickly and enforce it strictly. Charging the fee of water rights is needed and government should prevent residents to pump groundwater and rivers over their rights. Keeping water sources abundant will help us to use sustainablely.
3. Water of pond in farm should be increased to 83~2200 million tons, as well as 3571~3953 million tons for Irrigation return flow. Government can encourage farmers to vary fallow into ponds so that water in wet season can be cumulated for the agricultural using in dry season. We should renew the hydraulic infrastructure to recycle irrigating water sufficiently and to prevent leaking during transportation.
4. Separate industrial water supply system from residential water. As to the raw water for industries, government can give a lower price under certain quantity to keep up with the price of neighbor countries. We can also encourage industries to develop water sources on their own or buy water rights.

V. References

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