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Abstract

In a region with shared water aquifers, the use of water by one country becomes an externality to another. A policy to subsidize water is shown to lead to both countries being made worse off, but is likely to be supported by special interests having water rights, and those in sectors such as agricultural that uses water relatively intensively. The unilateral water tax will reduce own country's GNP and rise GNP in the other country. Only when both countries impose a tax cooperatively, will GNP rise in both countries.

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1. Introduction

The water resources of Israel, Jordan, Gaza and the West Bank are limited and their use by one impinges on the use by another. This paper focuses on water use by one region as an externality to another in an environment where one region is relatively more endowed with capital so that its comparative advantage lies in manufacturing while the other lies in agriculture. Water consumption in this area has been outstripping currently sustainable water yields, resulting in a drop in water tables and the infiltration of seawater into aquifers (Berck and Lipow, 1994). Even though agriculture contribute less than 7% to GNP in Israel and 13% in Jordan, the sector uses 75% of total water supplies. Moreover, the cost of water tends to be heavily subsidized by most of countries in this region. (Naff, 1994). As this area continues to develop and become more open to world markets, increased pressures are likely to be placed on already limited supplies of water. These pressures will surely encourage further reconsideration of water policy, and how own country and other country policy will impact on water use, the sectoral composition of output, and returns to factors of production. Questions as to the nature of the strategic interdependence that water imposes on policy, and the gains and losses form cooperative versus non-cooperative behavior are likely to be among issues at the top of the policy agenda. Since water is an economy wide resource, a general equilibrium framework is the best tool to deal with such issues.

Given that water resources are limited, pumping groundwater from an aquifer by one country tends to reduce the amount of water available to another while increasing pumping costs and the risk of harm to the aquifer. This kind of an externality is usually dealt with in the context of property rights where free access can result in a "tragedy of commons". (Brill & Hochman, 1994). This paper does not focus on the property right problem per se; instead, we mainly analyze the inter-country effects of water policy. A simple model is presented in the next section, and its general equilibrium characteristics described in section 3. The model is developed to capture essential water-linkage characteristics of economies in this region. Section 4 is divided into four sub-sections where a numerical example is presented. A competitive equilibrium is analyzed in the first subsection. Due to the externality, the price of water, rents to holders of water rights and factor rental rates are shown to differ between the two countries. In the next sub-section, water subsidies are analyzed. It is shown that a subsidy in one country causes GNP to fall in both countries, but the indirect effect on the other country is greater than the negative direct effect on the country imposing the subsidy. Various levels of unilateral and bilateral water taxes are considered in the third subsection. These results confirm that the competitive equilibrium with no tax or subsidy is equivalent to a prisoner's dilemma, while the cooperative solution is to impose a water use tax in both countries. The effect of relative differences in the efficiency of water generation technology is considered in the last subsection. Summary and comments conclude the paper.

2. Basic Structure of the Model

There are two small open economies: A and B, each producing two final goods, X (manufacturing good) and Y (farm good) and one intermediate good, water H. Individual utility is a function of the two final goods, and assumed to be homothetic and identical across countries. Production of the final goods uses two primary inputs L and K and the intermediate input, water. The generation of water (pumping, processing, distributing) uses L and K as inputs, but the efficiency of these inputs is affected negatively by the level of water use in the other country. The final goods are tradable while water is non-tradable.

The primary inputs are mobile between the two final good and the one intermediate good sectors, but they are immobile across countries. While country A is assumed to own more K than country B, the amount of endowment L is assumed to be the same in both countries. By this assumption, country A is richer than country B. The final good technologies are constant returns to scale and identical across countries. Sector X is assumed to be K intensive and sector Y is L intensive, i.e.,the input ratio, $K_x/L_x > K_y/L_y$ holds for any factor prices. In addition, for each unit of output, sector Y is assumed to use more water than sector X, i.e.,$H_y/Y > H_x/X$.

To capture the scale effect of water generation, the technology to withdraw and distribute water is assumed to exhibit diminishing returns in L and K, hence, contrary to other sectors, there is positive profit or rent in this sector. The rent occurs to holders of water property rights. The technology of water is identical across countries; later this assumption is relaxed. Water is assumed to be extracted from a single aquifer shared by both countries. The capacity of the aquifer is fixed so the cost of water withdrawal depends on the water table of the aquifer. Consequently, generating water from this aquifer by one country will reduce the water table and increase the water extraction costs of the other country. In this simple static model, we assume that the aquifer is replenished in the rainy season. The interdependence between countries is the negative externality emanating from the effect of one country's water consumption on the other's cost of water extraction. That is, for the same levels of capital and labor, the amount of water generated by country A (B) is smaller if the supply of the water from country B (A) increases. Thus, the water generation function can be written as

$$H^A = h(L_h^A, K_h^A, H^* - H^B),$$

$$H^B = h(L_h^B, K_h^B, H^* - H^A),$$

where H^* is the fixed amount of water in the aquifer. H^i is strictly increasing and constant returns to scale in $(L_h^i, K_h^i, H^* - H^j) \in R^3_+$ and hence decreasing returns to scale in (L_h^i, K_h^i). As country j's water supply enters country i's water generation function negatively, we have $\partial H^A / \partial H^B < 0$ and $\partial H^B / \partial H^A < 0$.

3. General Equilibrium with a Shared Aquifer

For the small open economy without any policy distortion, the equilibrium prices for tradable goods, P_x and P_y are treated exogenously, and hence the unit cost functions for X and Y equal the equilibrium prices. I.e.,

$$c_x(w^i, r^i, P_h^i) = P_x$$

$$c_y(w^i, r^i, P_h^i) = P_y,$$

where w^i is wage, r^i is capital rent and P_h^i is the water price final good producers pay. In the absence of externalities and policy distortions, this price should be equalized among the final good producers, and equal to the marginal cost of water generation within each country.

The rent from water generation is the difference between water revenue and its production cost. Since the term $H^* - H^j$ in the function is not a choice variable in the i-th country, the maximized rent can be written as

$$\Pi_h(w^i,r^i,P_h{}^i,H^i) = \pi_h(w^i,r^i,P_h{}^i)H^i,\ i = A, B.$$

where $H^i = H^*-H^j$, $i \neq j$, is an externality term, and $\pi_h(.)$ can be treated as a shadow price of the rights to access the water resource. Then, from the envelope theorem, the supply function of water can be derived by differentiating $\Pi_h(.)$ with respect to $P_h{}^i$. As a non-tradable good, the price of water can be derived as a function of the final good prices and the externality term by setting its supply being equal to its demand. I.e., $P_h{}^i = P_h(P_x,P_y,H^i)$. Usually, a non-tradable good price should be equal between countries if the model has only two final good production sectors and two primary inputs. However, as there exists an externality in our model, if H^A is not equal to H^B, that is, if two countries generate and use different amounts of water (which is common when the water input and final good output ratios are different between industries, and when the outputs of final good production sectors are different between countries) then the marginal cost and hence the price of water can differ between countries.

Prices for primary inputs, w^i and r^i can be solved from the final good unit cost functions, expressed as a function of the final good prices and water price, and then, as a function of the final good prices and the externality. I.e,

$$w^i = w^i(P_x,P_y,H^i)$$

$$r^i = r^i(P_x,P_y,H^i),\ i = A, B.$$

Even though the technologies of final good production are identical across countries, the wages and capital rental rates differ if H^A differs from H^B.

From the market clearing conditions for endowments, and the equilibrium condition for water, the supply of X and Y can be expressed as the function of the final good prices, endowments and the externality. I.e.,

$$X^i = X(P_x,P_y,\bar{L}^i,\bar{K}^i;H^i)$$

$$Y^i = Y(P_x,P_y,\bar{L}^i,\bar{K}^i;H^i).$$

The aggregate demand functions for X and Y can be derived from maximizing aggregate utility given GNP as a budget constraint:

$$X_i = x(P_x,P_y,GNP_i)$$

$$Y_i = y(P_x,P_y,GNP_i),$$

where

$$GNP_i = w^i(P_x,P_y,H^i)\bar{L}^i + r^i(P_x,P_y,H^i)\bar{K}^i + \pi_h(w^i(P_x,P_y,H^i),r^i(P_x,P_y,H^i),P_h{}^i(P_x,P_y,H^i))H^i,$$

which is defined by the returns to endowments and the rents to holders of water rights.

Excess demand is given by:

$$EX_i = X_i - X^i$$

$$EY_i = Y_i - Y^i.$$

Since $\bar{L}^A = \bar{L}^B$, $\bar{K}^A > \bar{K}^B$, and since X is capital intensive, country A exports (imports) X (Y) while country B has the opposite trading pattern.

Further, since each country's water supply is an externality in the other country's water supply function, a competitive equilibrium is equivalent to a Nash equilibrium. That is, if the firm in each country's water sector maximizes its profit given the other country's water supply being at its optimal level, under competitive equilibrium, a Nash equilibrium can be obtained. It is easy to see that the supply of water in country j not only affects country i's supply of water, but also this country's supply of final good X and Y, the unit cost of factor inputs w and r, the price of water, P_h, the profit of water extracting, Π_h, and the national income, GNP. Furthermore, as consumer's demand for final goods depends on GNP, the demand for X and Y is affected indirectly.

Hence, as two countries share a common water aquifer, the general equilibrium linkages between them becomes surprisingly complicated and inter-linked. Effectively, any policy affecting the equilibrium in one country affects the other country's water supply and demand. In the next section, we use a simple sample economy to describe and discuss the nature of these linkages.

4. General Equilibrium Effects of Water Policies

Of the two countries in this sample economy, A can be viewed as representing Israel, and B represents the West Bank, Gaza and perhaps Jordan. All assumptions made in section 2 are satisfied here. The production functions for X and Y, the water generation function and utility function are presented in Appendix. First we consider the case where the technology of water generation is identical across countries.

4.1 Competitive Equilibrium with No Water Policy

Since water is non-tradable between countries, at the equilibrium, country A's manufacturing sector accounts for 84% of GNP and agriculture the remainder (16%). Country B's manufacturing sector is 54% and agriculture is 46% of its GNP. Without any policy distortion, the equilibrium results show that country A has comparative advantage in manufacturing as the output of its manufacturing sector is 99% higher than B's, while country B has comparative advantage in agriculture with an output 1.2 times higher than A's. As a result, country A exports the manufacturers good X and imports the agricultural good Y from the rest of the world while B has the opposite position. Country A's exports account for 28.3% of its manufacturing output and imports are 1.45 times its agricultural output. In the case of B, exports account for 13.8% of its agricultural output and the imports account for 18.4% of its manufacturing output. Since agriculture uses more water for per unit of output, the water supply and demand in country B is 7.2% higher than in country A.

Contrary to the Heckscher-Ohlin framework, the different water supply and demands results in different prices for water and primary factor inputs. The price of water in country A is 0.15% higher than in country B, while the wage-capital rental ratio in country B is 0.7% higher than in country A.

4.2 Effects of the Subsidy Policy

As the equilibrium solution of this model has a Nash equilibrium property, the behavior of the policy makers in each country is easily modeled as a one shot Nash game. First, consider the case of a water subsidy. The subsidy may result from the rent seeking of agricultural producers as a way to combat import competition and or the holders of water rights. We have simulated three possibilities for this policy: (a) only country A subsidizes water, (b) only country B subsidizes water, and (c) both countries subsidize water.

A pervasive general equilibrium result, regardless of whether subsidies are unilateral or bilateral, is that GNP always falls in both countries. This result is shown in Appendix, Figure 1 - 3. Notice that if only country A subsidizes, GNP falls more in country B than in country A, while if only country B subsidizes, GNP falls more in country A than in country B. Hence, the indirect effect of the subsidy tends to harm the other country more than the direct effect on the country imposing the subsidy. If both subsidize, the decline in GNP is larger for both countries. Whether the rather perverse dominance of the indirect effects over the direct would predominate in a model collaborated to country data is unknown. Nevertheless, the tendency for strong, though not necessarily dominant, indirect effects would likely remain.

The decline in GNP is the result of the changes in the supply of final goods. As the subsidy policy causes the unit cost of water to users to fall, the demand for and supply of water increase in the country where water usage is subsidized. The increased supply in the subsidized country causes the cost of water generation in the other country to increase since water supply is a negative externality in the other country's function. Table 1 presents the affect of water subsidies on water prices.

Table 1. % Changes in the Prices of Water after Subsidy

The subsidy rates are 0.05 -- 0.15

Subsidizing countries	Country A	Country B	Both Countries
Water Price in Country A	(+) 1.29 to 4.11	(+) 0.59 to 2.17	(+) 1.88 to 6.24
Water Price in Country B	(+) 0.52 to 1.89	(+) 1.28 to 4.07	(+) 1.80 to 5.91

The sign (+) indicates that the change is positive. The two numbers in each cell indicate the range over which the price of water varies. The results in Table 1 indicate that the price of water rises in both countries regardless of who subsidizes. However, the user's price of water only rises in the no subsidy country while in the subsidized country the user's price falls. This results because the use of water increases in the subsidizing country which raises water costs in the other country so that its use of water falls. If both subsidize, the water supply increases in both countries (see Table 2).

Table 2. % Changes in Water Supply and Demand after Subsidy

The subsidy rates are 0.05 -- 0.15

Subsidizing countries	Country A	Country B	Both Countries
Water Supply in A	5.64 to 18.88	- 0.96 to - 3.47	4.65 to 15.02
Water Supply in B	- 0.82 to - 2.96	5.48 to 18.34	4.63 to 15.08

The supply of final goods are also affected by a water subsidy. When only country A subsidizes, the supply of manufacturers falls and agriculture rises in country A while manufacturing rises and agriculture falls in country B. When only country B subsidizes, supply of manufacturers rises and agriculture falls in country A while manufacturers falls and agriculture rises in country B. These results are presented in Table 3 and imply that a country's agricultural sector can be benefited from an own subsidy and be harmed by the other country's subsidy, while a country's manufacturing sector can be harmed by its own country subsidy and can be benefited from the other country's subsidy.

Table 3. % Changes in Supply of Final Goods after Subsidy

The subsidy are 0.05 -- 0.15

Subsidizing countries		Country A	Country B	Both Countries
Country A	X	(-) -1.65 to -5.44	(+) 0.19 to 0.70	(-) -1.46 to -4.73
	Y	(+) 8.45 to 27.04	(-) -1.54 to -5.63	(+) 6.91 to 21.49
Country B	X	(+) 0.31 to 1.13	(-) -3.17 to -10.44	(-) -2.85 to -9.30
	Y	(-) -0.59 to -2.15	(+) 3.65 to 11.67	(+) 3.05 to 9.55

From the perspective of comparative advantage with the rest of the world, when Country A subsidizes water, both countries' export industries are implicitly taxed, and hence the exports of these sectors fall. If country B subsidizes water usage, then both countries' export industries are implicitly subsidized. When both countries subsidize, the supply of manufacturers falls and agriculture rises in both countries. Furthermore, the rise in agricultural output in country A, which does not have comparative advantage in this sector, is greater than in country B.

The water subsidy can also encourage rent seeking on the part of groups holding water rights. As the technology of water generation exhibits diminishing returns to scale, holders of water rights obtain positive rents. Simulation results show that the rent to water rights increases in the country imposing the subsidy while it decreases in the other country. Hence, a non-cooperative game between holders of water rights in the two countries obtains. When both countries impose water subsidies, the profits increase in both countries. These results are shown in Appendix, Figure 4 - 6.

Hence, a country's water rights policy, such as licensing, will benefit the interest group who has such rights, while the subsidy policy in the other country will hurt it. The increased rent to water rights not only occurs from the increase in the water supply, but also from the increase in water price, since as Table 1 shows that the producer price of water rises in both countries after subsidy and it rises more in the country imposing the subsidy.

Labor and capital rental rates are also affected by the subsidy; these are changes are summarized in Table 4.

Table 4. % Changes in the Factor Prices after Subsidy, the subsidy rates are 0.05 -- 0.15

Subsidizing countries		Country A	Country B	Both Countries
Country A	w	2.03 to 6.61	-0.31 to -1.12	1.73 to 5.49
	r	-0.18 to -0.58	0.03 to 0.10	-0.16 to -0.48
Country B	w	-0.27 to -0.98	2.04 to 6.64	1.77 to 5.66
	r	0.02 to 0.09	-0.18 to -0.58	-0.16 to -0.50

Table 4 shows that wage rental rates rise and capital rental rates fall in the country imposing a subsidy while wage falls and capital rental rates rise in the country not subsidizing water. In the case of a unilateral subsidy, wage rises and capital rental rates fall in the both countries. The main reason for these results is that agriculture is labor intensive, while manufacturing is capital intensive. As the water use subsidy causes the supply of the agricultural good to increase and the supply of manufacturing good to decrease, demand for labor increases relative to the demand for capital. Hence, labor becomes more expensive while capital becomes cheaper in the subsidy country. On the other hand, as the supply of agriculture falls, wage falls and capital rental rate rises in the no subsidy country.

4.3 Effects of Tax Policy

Usually, a tax policy can be chosen to reduce the degradation of a common resources like water. However policy makers typically only consider the effects on their own country and ignore the negative effects on other countries. Similar to the above analysis, we simulate three possible choices: (a) only country A taxes, (b) only country B taxes, (c) both countries tax. One choice is equivalent to the Pareto optimal solution over both countries.

The simulation results show that GNP falls in the country imposing the tax, while GNP rises in the other country. However, if both countries adopt such policy, both countries can be made better off! Thus, if policy is required to prevent a deterioration of the aquifer, say from salt water incursion, then, without cooperation, one country may be induced to free ride on the other country's efforts to conserve the resource. These results are shown in Appendix, Figure 7 - 9. A Nash equilibrium is shown in Table 5.

Table 5. % Changes in GNP of Nash Equilibrium with Tax, tax rate is 0.10

Country B Country A	No Tax	Tax Water
No Tax	(0; 0)*	(0.144; -0.104)
Tax Water	(-0.078;0.174)	(0.069; 0.074)**

*The Nash solution. **The cooperative solution.

Table 5 shows in the lower left cell that, if country A imposes a tax rate of 0.1 on users of water, then its GNP falls 0.078% while country B's GNP rises 0.174%. If country B taxes, its GNP falls 0.104% while country A's GNP rises 0.144%. Thus, without cooperative behavior, no country is likely to impose a tax unilaterally. Obviously, the Nash equilibrium is equivalent to a Prisoner's dilemma. But, under cooperative behavior, if both countries tax, country A's GNP rises 0.069% and B's rises 0.074% at tax rate of 0.1.

The main reason for the fall in GNP of the country imposing the tax unilaterally is that the rise in the unit cost of water causes the supply and demand for water in the taxing country to fall. This decline lowers the negative effect on the water supply of the other country, which in turn, results in an decline in the unit cost of water in the other country. Table 6 presents the changes in water price after tax.

Table 6. % Changes in the Prices of Water after Tax, the tax rates are 0.05 -- 0.15

Taxing countries	Country A	Country B	Both Countries
Water Price in A	(-) -1.23 to -3.50	(-) -0.49 to -1.28	(-) -1.72 to -4.78
Water Price in B	(-) -0.44 to -1.15	(-) -1.21 to -3.46	(-) -1.65 to -4.61

A tax causes the price of water to holders of water rights to fall in both countries regardless who taxes. As this price of falls, the demand for water and hence the supply of water increase in the no tax country. However for the taxing country, the user price of water rises after the tax. Thus, we observe that the decline in the supply and demand of water in taxing country is greater than the increase in the same indicator in the non-tax country (see Table 7).

Table 7. % Changes in Water Supply and Demand after Tax, the taxes are 0.05 -- 0.15

Taxing countries	Country A	Country B	Both Countries
Water Supply in A	(-) -5.11 to -14.01	(+) 0.81 to 2.15	(-) -4.32 to -12.09
Water Supply in B	(+) 0.71 to 1.86	(-) -4.97 to -13.65	(-) -4.29 to -11.97

Since agriculture is the intensive user of water, its production falls. Even though the supply of water to the less intensive sector, manufacturing, rises slightly, the increase is smaller than the decline in agriculture. Hence, GNP falls in the taxing country. On the other hand, in the non-taxing country, the increase in agriculture is greater than the decrease in manufacturing, which thus results in a positive change in its GNP. Such supply effects are shown in Table 8.

Table 8. % Changes in the Supply of Final Goods after Tax, the tax are 0.05 -- 0.15

Taxing countries		Country A	Country B	Both Countries
Country A	X	1.52 to 4.24	- 0.16 to - 0.42	1.36 to 3.82
	Y	- 7.97 to - 22.65	1.31 to 3.42	- 6.66 to - 19.26
Country B	X	- 0.27 to - 0.70	2.91 to 8.09	2.65 to 7.41
	Y	0.51 to 1.34	- 3.44 to - 9.77	- 2.93 to - 8.44

As Table 7 shows, when both countries tax, the supply of and demand for water fall in both countries, but in each country the falling rates are smaller than if a tax is imposed unilaterally. Consequently, the decline in agriculture is smaller than in the case of a unilaterally tax, as shown in Table 8. Hence, both country's GNP rises and both are made better off. Furthermore, when both countries tax, the supply of agricultural sector falls less in country B (where its comparative advantage lies) than in country A.

Figure 9 (for both countries tax) also shows that there exists an optimal level of taxes for the two countries as the change in GNP to tax levels is concave. The versicle axis measures the percent change in GNP relative to the no tax level of GNP. Hence, over the entire domain of the tax rate shown on the horizontal axes, GNP in both countries rise. The level of bilateral taxes that maximize both countries' GNP is shown at 0.1.

In fact, the optimal level tax can be solved from a cooperative optimization problem. That is, by maximizing two countries' total GNP, subject to the resource constraints in each country:

$$\text{Max } P_x(X^A+X^B) + P_y(Y^A+Y^B)$$

$$\text{s.t. } X^i = F(L_x^i, K_x^i, H_x^i)$$

$$Y^i = G(L_y^i, K_y^i, H_y^i)$$

$$H_x^A+H_y^A = h(L_h^A, K_h^A, H^*-(H_x^B+H_y^B))$$

$$H_x^B+H_y^B = h(L_h^B, K_h^B, H^*-(H_x^A+H_y^A))$$

$$L_x^i+L_y^i+L_y^i = \bar{L}^i$$

$$K_x^i+K_y^i+K_y^i = \bar{K}^i, \ i = A, B.$$

From the first order condition for this optimal problem, the users in each country not only pay the price of water they use, but they also pay the damage caused by their use on the other country's supply of water. That is,

$$P_x(\partial X^i / \partial H_x^i) = \lambda_h^i + \lambda_h^j(\partial H^j / \partial(H^*-H^i))$$

$$P_y(\partial X^i / \partial H_y^i) = \lambda_h^i + \lambda_h^j(\partial H^j / \partial(H^*-H^i))$$

where λ_h^i is the shadow price of water in country i, i = A,B. The marginal damage of the externality, $\partial H^j / \partial(H^*-H^i)$, is equal to the negative shadow price of water rights, and it is equal to the tax rate adjusted by the price of water in the country. I.e.,

$$t^i = (\partial H^i / \partial H^i)(P_h^i/P_h^j), \ i \neq j.$$

The simulation result of optimal tax rates solved from the above optimal problem is 1.099447 for country A and 1.099407 for country B.

The tax policy affects rents to holders of water rights. Simulation results show that the rents fall in the country imposing, unilaterally, taxes on water. When both countries tax, the rents to water rights fall in both countries. These results are shown in Appendix, Figure 10 - 12. Almost surely, the decline in rents to holders of water rights will give rise to their willingness to engage in collective action to prevent such a policy.

The changes in factor prices are presented in Table 9.

Table 9. % Changes in the Factor Prices after Tax, the tax are 0.05 -- 0.15

Taxing countries		Country A	Country B	Both Countries
Country A	w	(-) -1.89 to -5.31	(+) 0.26 to 0.68	(-) -1.63 to -4.65
	r	(+) 0.17 to 0.50	(-) -0.02 to -0.06	(+) 0.15 to 0.43
Country B	w	(+) 0.23 to 0.61	(-) -1.90 to -5.33	(-) -1.67 to -4.73
	r	(-) -0.02 to -0.05	(+) 0.17 to 0.50	(+) 0.15 to 0.44

In contrast to the simulation results reported in Table 4, where changes in factor prices after subsidy are shown, taxes and subsidies affect factor price contrarily. The reason is the same as given for Table 4.

4.4 Effects of Different Technology

Now, we relax the identical technology assumption and assume that country A has a more efficient technology in water generation. Let the technical coefficient d_a in country A be 1.01 and d_b be still 1. Because of this assumption, the price of water in country A falls relative to the price of water in country B. (Under the same technology assumption, the price of water is lower in country B.) The result is that more water is consumed in country A. Consequently, the price of water rises in country B, leading to a fall in its supply of and demand for water.

A cheaper water supply in country A causes its supply of manufacturing to decrease and agriculture to increase since agriculture is the relatively intensive user of this economy wide resource. On the other hand, a more expensive water supply in country B causes that the opposite results to obtain. Thus, country A's GNP rises while country B's GNP falls relative to the status quo of identical technologies. These results are presented in Table 10.

Table 10. Simulation Results Caused by Changing in Technology of Water Supply (%)

	Country A	Country B
Price of water	-3.926	0.628
Supply of water	6.796	-0.996
Supply of X	-1.324	0.378
Supply of Y	10.721	-0.721
GNP	0.631	-0.132

5. Conclusions

Treating water policy choices as a set of Nash equilibrium strategies, a policy to subsidize water is shown to lead to both countries being made worse off, as is also shown to be the case of a no water's policy. A policy to subsidize water yields higher rents to the holders of water rights, and to those whose incomes are derived from the sectors using water relatively intensively, i.e, agriculture. Thus, under some not unreasonable political environments, "bad policy" is likely to be supported by special interests having water rights, and those in sectors such as agricultural that uses water relatively intensively.

To internalize the negative effects of water use in one country on those in another, as well as to retard the degradation of water resources, a tax policy should be considered. However, unilaterally imposing tax will reduce own country's GNP and rise GNP in the other country. Only when both countries impose a tax simultaneously, will GNP rise in both countries. Still, a cooperative tax policy only benefits both countries' manufacturing sector, while agricultural output will fall as will rents to holders of water rights. Our analysis ignored the question of water rights. In the absence of water rights, agents would attempt to compete for the positive rents to holders of these rights, eventually driving rents toward zero. The result would be similar to our analysis of the effects of subsidies, which as these results suggest, tend have greater and negative other country effects than they have on own country effects.

The analysis here is clearly abstract and hypothetical. Nevertheless, it raises key questions that appear to be of key importance and worthy of further investigation. The next step should entail a far more detailed investigation which relies on country data. Since water is an economy wide resource, a broad based economy wide framework appears to be required.

Appendix

1. Production functions for X and Y

$$X = F(L_x,K_x,H_x) = L_x^{0.25} K_x^{0.65} H_x^{0.1}$$

$$Y = G(L_y,K_y,H_y) = L_y^{0.5} K_y^{0.25} H_y^{0.25}$$

which are identical for both countries, and L_i is labor, K_i is capital and H_i is water used in sector i.

2. Water extracting technology

$$H^A = h_A(L_h^A,K_h^A,H^B) = d_a L_h^{0.4} K_h^{0.5} (H^*-H_B)^{0.1}$$

$$H^B = h_B(L_h^B,K_h^B,H^A) = d_b L_h^{0.4} K_h^{0.5} ((H^*-H_A)^{0.1}$$

where d_i is technical coefficient. For the first model it is assumed to be unity for both countries, and for the second model, d_a is greater than one and d_b is still one.

3. Utility function

$$u_i = U(X_i,Y_i) = X_i^{0.6} Y_i^{0.4}$$

4. Factor endowments

$$\bar{L}^A = 100, \bar{L}^B = 100,$$

$$\bar{K}^A = 180, \bar{K}^B = 120.$$

5. Equilibrium output prices

$$P_x = 0.75, P_y = 1.$$

Figure 1. % Changes in GNP When Country A Subsidizes Water

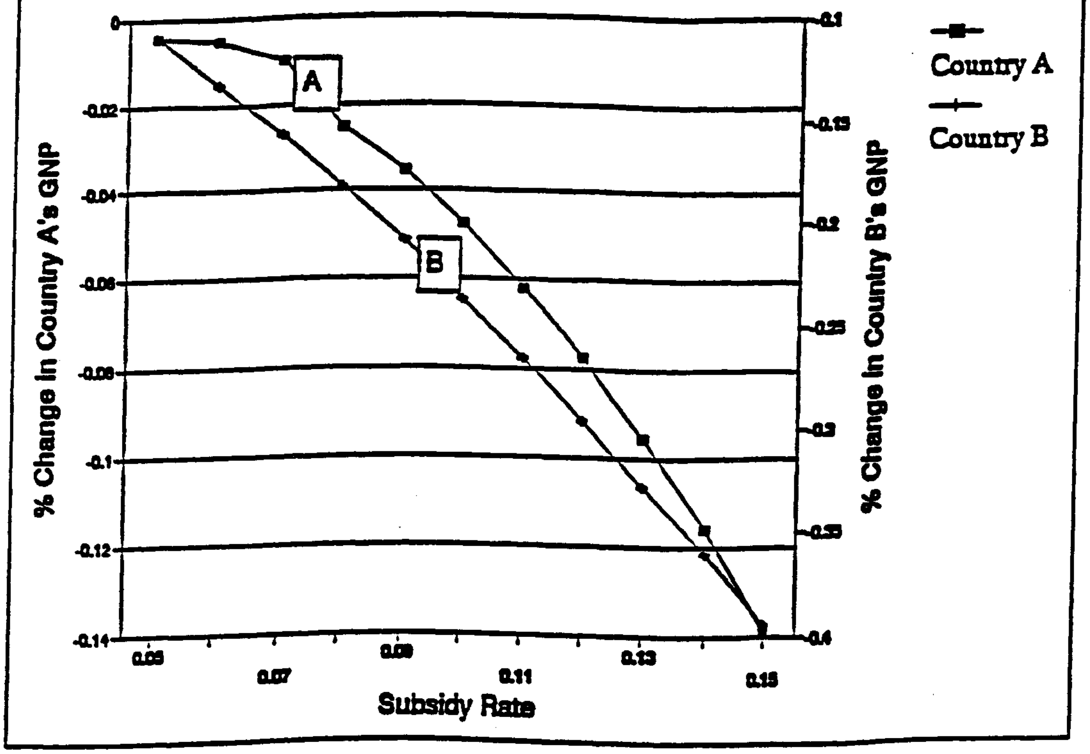


Figure 2. % Changes in GNP When Country B Subsidizes Water

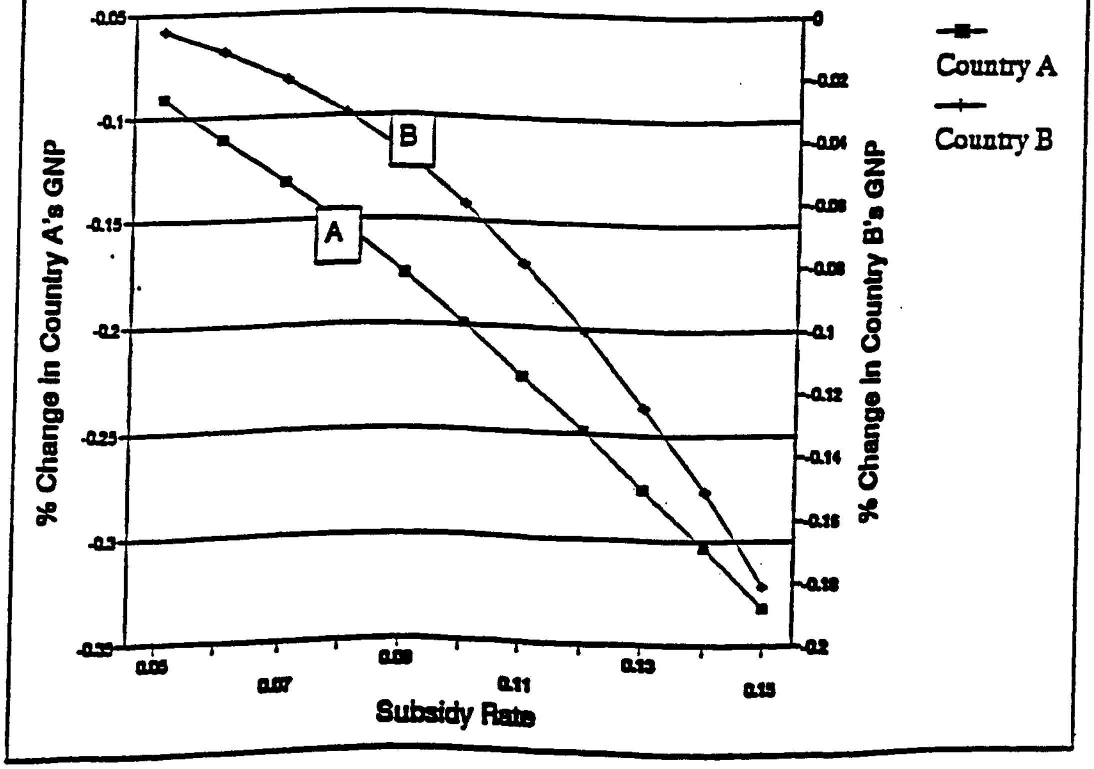


Figure 3. % Changs in GNP
When Both Countries Subsidize Water

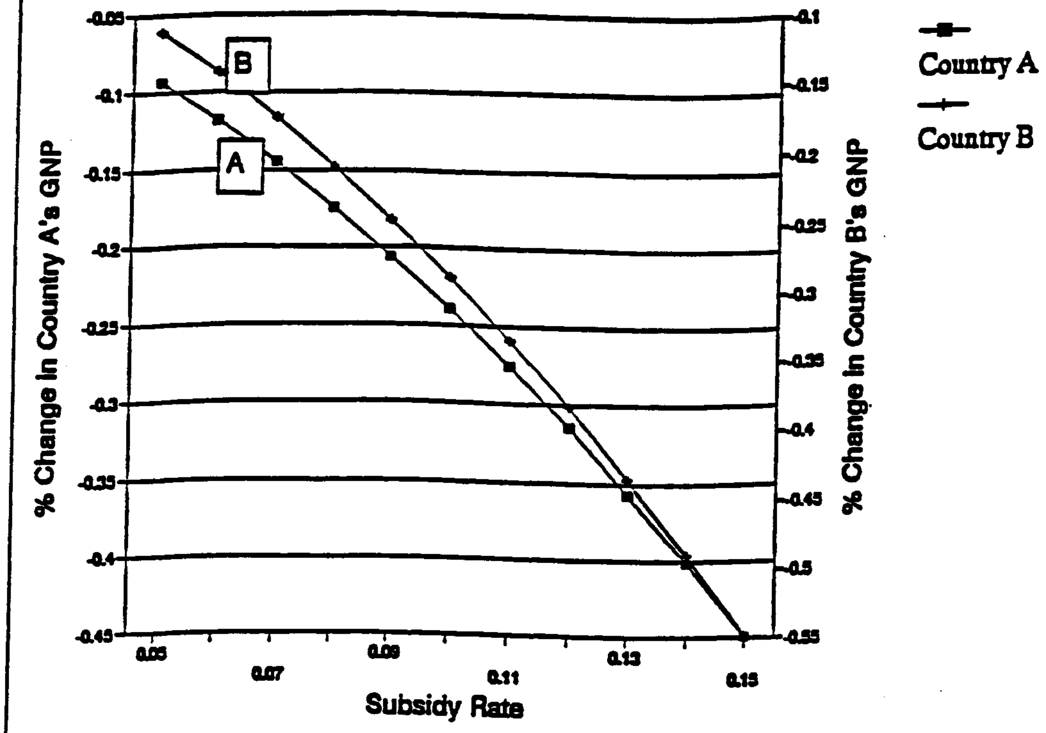


Figure 4. % Changes in GNP
When Country A Taxes on Water

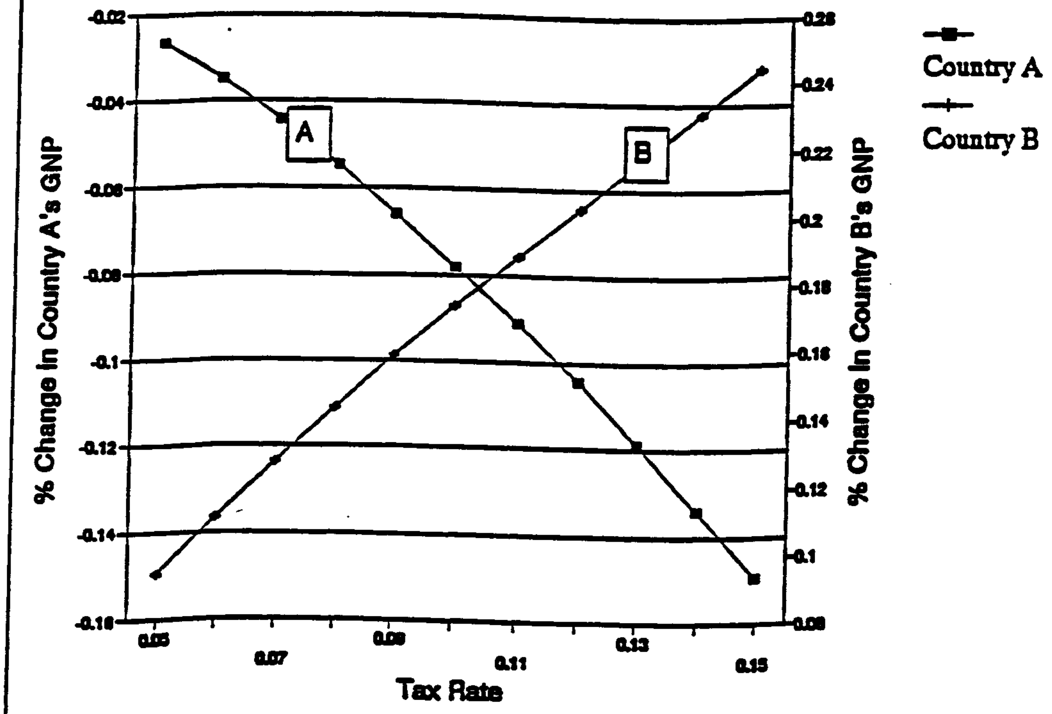


Figure 5. % Changes in GNP
When Country B Taxes On Water

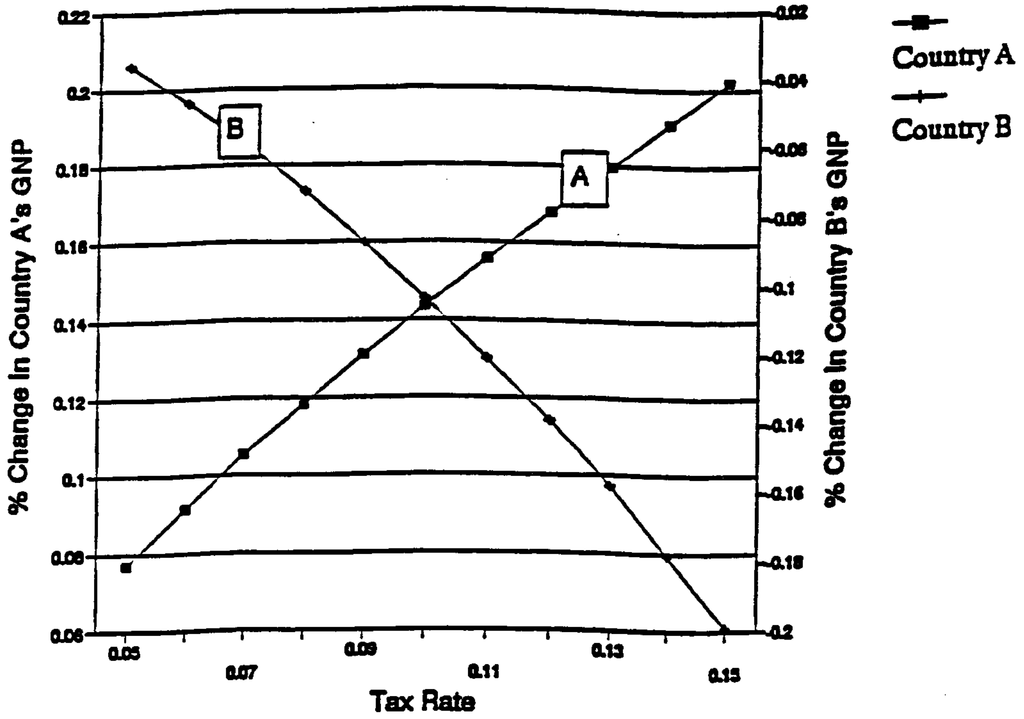
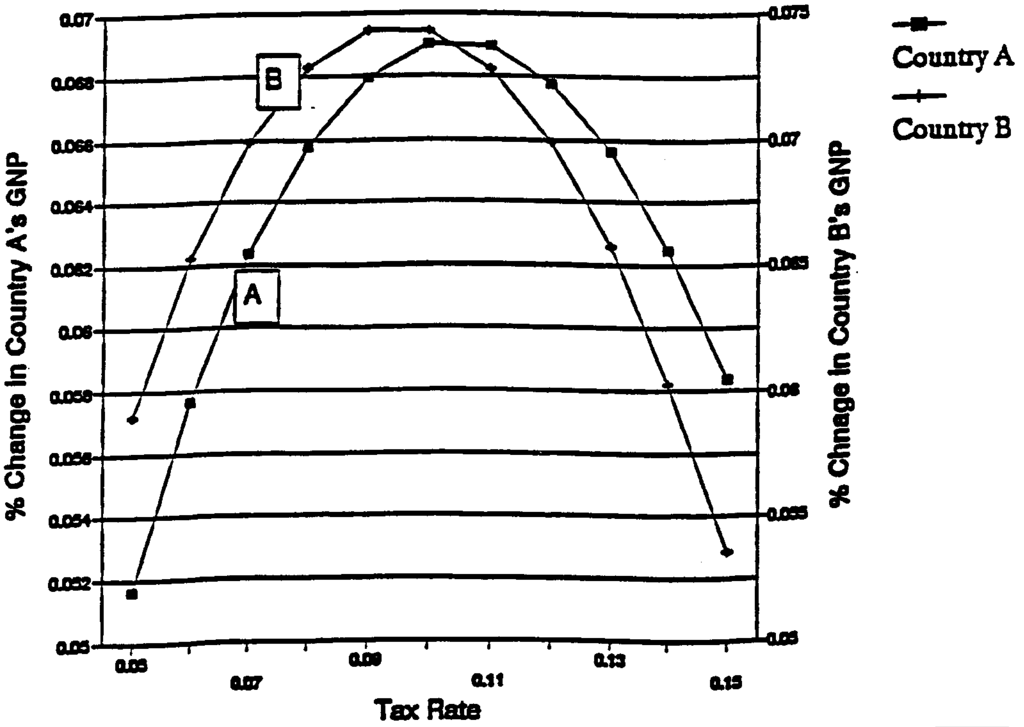


Figure 6. % Changes in GNP
When Both Countries Tax on Water



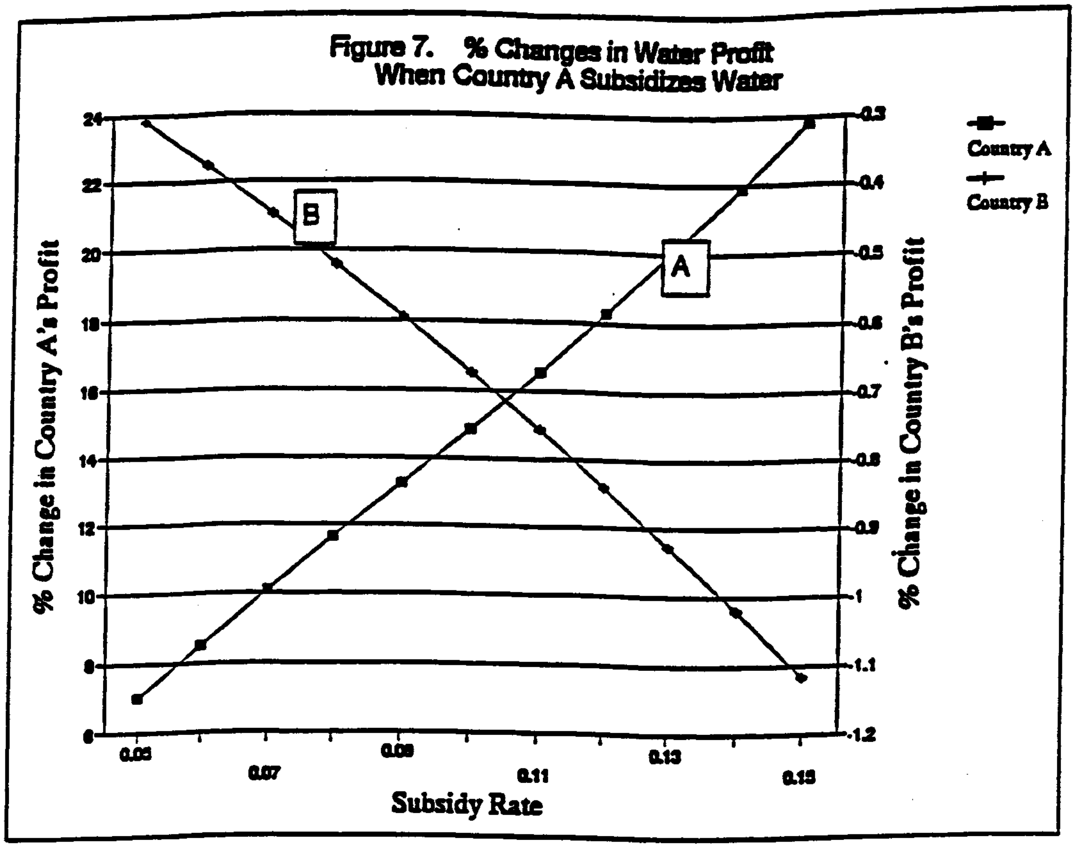


Figure 7. % Changes in Water Profit When Country A Subsidizes Water

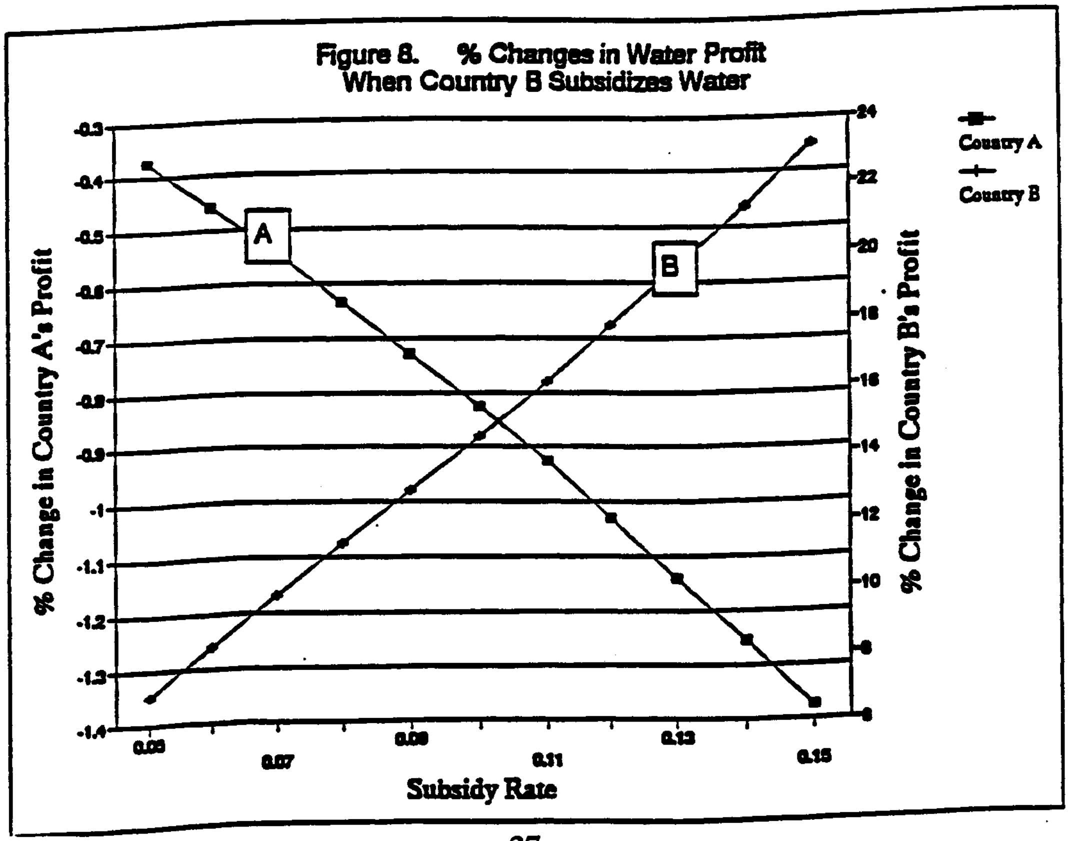


Figure 8. % Changes in Water Profit When Country B Subsidizes Water

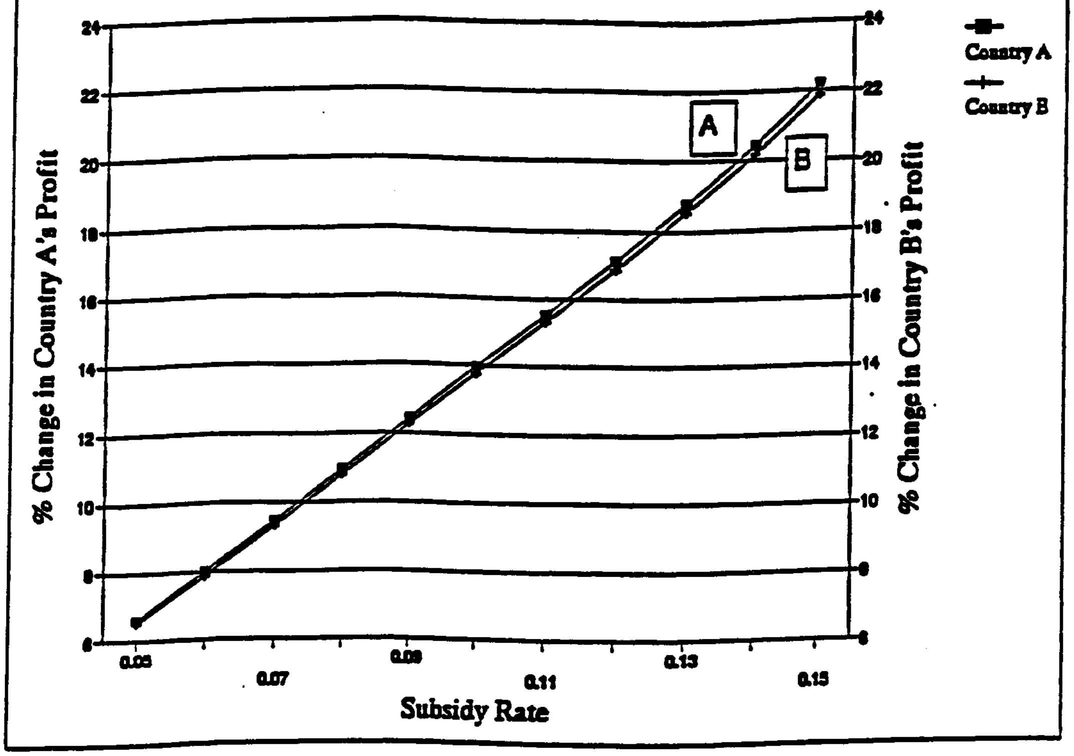


Figure 9. % Changes in Water Porfit When Both Countries Subsidize Water

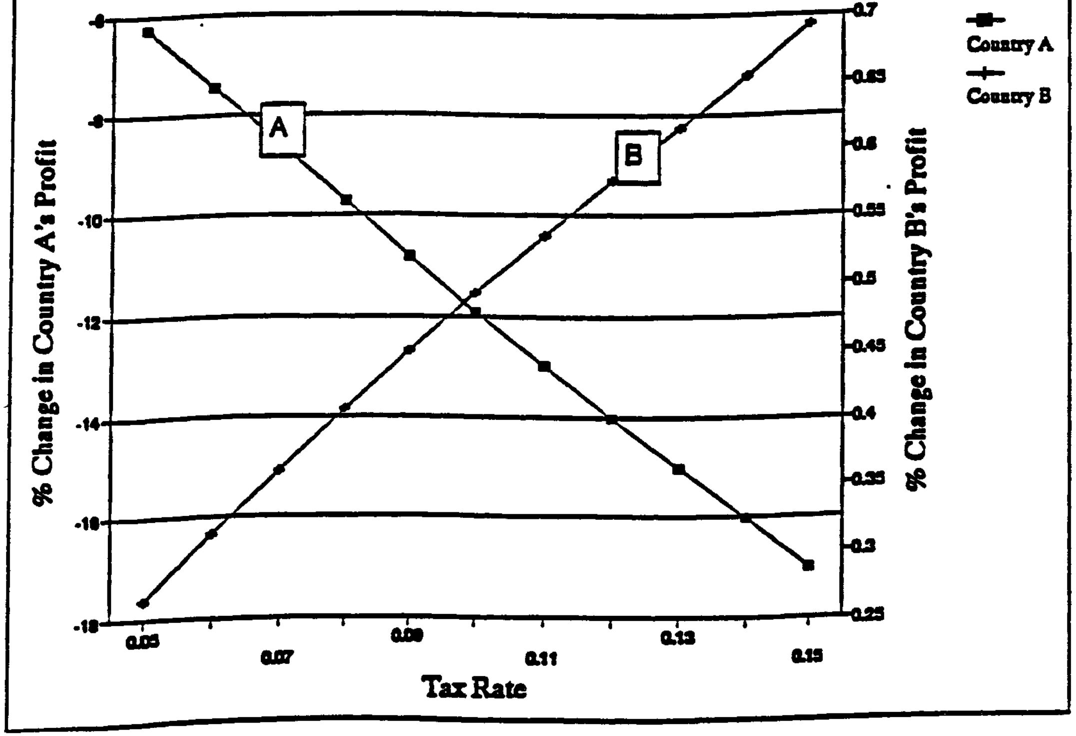


Figure 10. % Changes in Water Profit When Country A Taxes on Water

Figure 11. % Changes in Water Profit When Country B Taxes on Water

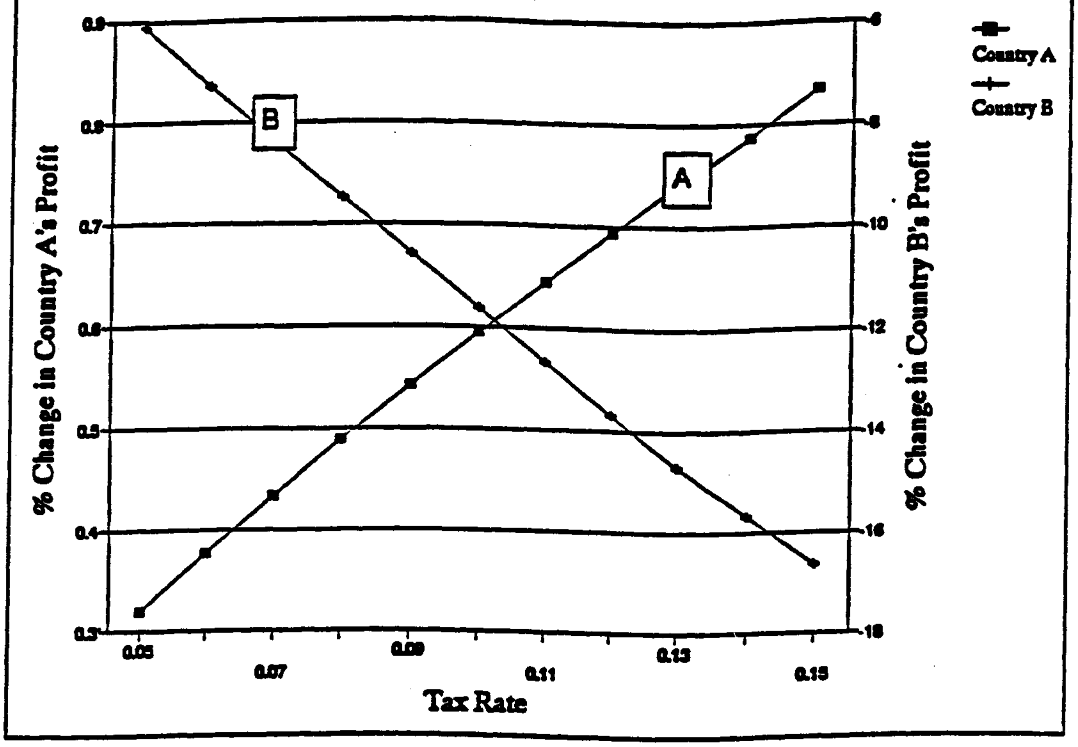
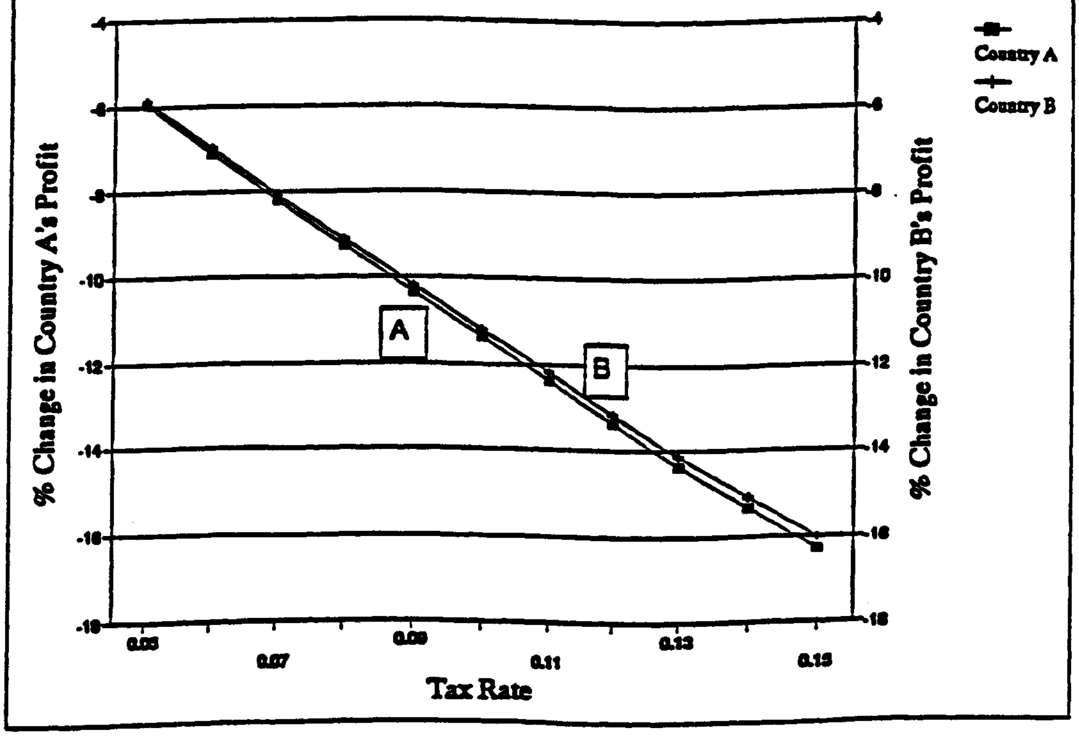


Figure 12. % Changes in Water Porfit When Both Countries Tax on Water



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