Application of Computable General Equilibrium Model to Derive Impacts of Surface Water Reallocation Policy

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Introduction

The allocation of water is an important consideration in the western United States. An emerging issue is the regional economic trade-offs between out-of-stream use for irrigated agriculture and the use of water in Nevada's Stillwater National Wildlife Refuge wetlands for supporting various recreation activities such as angling, wildlife observation, and water fowl hunting. Estimated visitation at the Stillwater Marsh Area has ranged from 28,000 to 40,000 visits annually. This has generated expenditures of more than $1.1 million, which translates into an additional $440,000 of direct and indirect income to Churchill County (Loomis).

This analysis estimates the impacts of reallocating surface water from agriculture to the Stillwater wetlands in Churchill County in northern Nevada using a dynamic county-level computable general equilibrium (CGE) model. In addition to the standard components of a dynamic county-level CGE, a recreation demand model from Smith and Kaoru is incorporated. Both economic impacts and changes in recreationists welfare caused by water reallocation are estimated.

Model Specification

Most economic policies have permanent effects on the time horizon, and therefore, the "time path" of the effects is a more appropriate object of analysis than the usual (comparative) static results of the policy effects. For a regional economy where many dynamic elements—such as interregional population movements and capital accumulation--are observed and where population grows quickly in a region such as Nevada, it is more appropriate to employ a dynamic specification of a CGE model than a static version. In this analysis, dynamics are explicitly incorporated into our county-level CGE model. This model is based on a previous model developed by Seung and Kraybill.

1. Churchill County CGE Model

Production: There are eight industries in the Churchill County dynamic CGE model. Three sectors are agricultural sectors—(i) livestock, (ii) other crops, and (iii) hay and pasture. The other five sectors are (iv) mining, (v) construction, manufacturing, transportation, and public utilities, (vi) trade, (vii) finance, insurance, and real estate, and (viii) services. Production technology in each sector is represented by a Cobb-Douglas value added function. Also, intermediate inputs are used in fixed ratios. Agricultural sectors use labor, capital, and land as production inputs. A fixed amount of water is combined with a unit of land in agricultural sectors for production. Thus, removal of a given amount of water from agriculture implies reduction in land use by these agricultural sectors. Non-agricultural sectors use labor and capital only.

Consumption: There are three types of households, which are (i) high income, (ii) medium income, and (iii) low income households. Preferences of the households are represented by a constant elasticity of substitution utility function. Utility maximization for each type of household subject to its budget constraint yields its demand function for each good.

Factor Mobility: In the dynamic CGE model, homogeneous labor is assumed to be perfectly mobile across sectors and partially mobile across regions. The assumption that labor is partially mobile across regions implies that there exist wage rate differentials between regions after the policy shock until the differentials disappear when the adjustment in local labor market is completed in the long run. Physical capital is sector-specific and once the physical capital is installed in a sector it is not mobile. However, the investible funds are perfectly mobile both intersectorally and interregionally. Capital stock in each sector is updated in each period as net investment (NI_t) is added to the capital stock.

Investment: The net output price of goods or services in sector i in time t ($PV_{i,t}$), the output level ($X_{i,t}$), and the return to capital ($R_{i,t}$) can be computed for a given value of installed capital ($K_{t-1,i}$) carried over from period (t-1) into period t. By substituting these values into the capital demand function, the desired level of capital, $KD_{i,t}$, is computed each period as follows:

(1) $$KD_{i,t} = \frac{\kappa_i \, PV_{i,t} \, X_{i,t}}{R_{i,t}}$$

where κ_i is the income share of capital in sector i. Net investment in each sector is given by

(2) $$NI_{i,t} = \lambda_i (KD_{i,t} - K_{i,t-1})$$

with $K_{i,t-1}$ given at the beginning of each period. The parameter λ_i represents the speed of stock adjustment. Equation (2) indicates that net investment is determined by the speed of adjustment times the disparity between the desired level of capital and its actual level.

The partial adjustment of net investment represented by equation (2) is consistent with the partial adjustment dynamics of labor migration. Thus, removing water from agricultural sectors reduces the amount of land used by the sectors, lowering agricultural outputs. This lowers the desired level of capital in the sectors through equation (1), leading to lower net investment in the sectors through equation (2). The investment determined via equation (2) above is independent of regional savings. Since regions are highly open economies and investment funds appear to be geographically mobile in the United States, it seems appropriate to treat the inflow of external savings as a residual that responds to the level of investment in the region. So if the region has more savings than needed for investment, the surplus savings flow out of the region, and vice versa.

Dynamics: In the model, there are two kinds of adjustment behavior to be considered (Robinson). First, in goods market, the adjustments of prices and quantities occur in a short period, say in a year, reducing excess demand to zero (Warlasian equilibria). Second, in factor markets, adjustment takes multiple periods because of lagged response of factor supplies. The sequence of equilibria generated without any policy implementation is called "continuous benchmark" while that generated with a policy shock is called "continuous counterfactual". Static equilibria are sequenced through time to reflect changes in capital and labor stocks due to investment, labor migration, and population growth. Calculation of equilibrium in each period begins with an initial capital endowment in each sector and a labor endowment for the economy as a whole.

2. Recreation Demand Model

Participation Equations: The data was obtained from the Nevada Division of Water Planning on (i) the number of days of angling, general recreation, and hunting, (ii) the annual acreage of Stillwater National Refuge, and (iii) the number of ducks. Using the data, a system of equations, in which the independent variables are water acreage at the wetlands, population, per capita real income, and number of ducks and the dependent variables are the numbers of trips to the wetlands for angling, general recreation, and hunting and number of ducks, was estimated. A seemingly unrelated regression method was used. The estimated coefficients are presented in Table 1. The system of equations shows that the size of Stillwater National Refuge has a positive influence on number of recreators in hunting and angling. Also, as the population in northern Nevada changes, general recreation and hunting both increase. The total number of trips are calculated as the sum of the numbers of trips for angling, general recreation, and hunting, which are updated in each period because of increase in population and change in per capita real income in northern Nevada area.

With the increase in acreage at the wetlands due to the water reallocation, the number of tourists and their accompanying expenditures will likewise increase. From the same data, we obtained the information about the expenditure patterns by northern Nevada residents who traveled to the Stillwater Wildlife area. From this data, the distribution of trip expenditures in Churchill County for trade sector (gasoline, food, and supplies) and for services sector (lodging) was estimated. According to the survey, the per trip expenditure that contribute to Churchill County economy is calculated to be $11.60 for trade sector and $12.50 for services sector. Thus, per trip total amount of expenditure which remains in Churchill County is $24.10.

By multiplying these per trip expenditures to the total number of trips to the wetlands in each period, we can calculate the change in final demand for trade sector and services sector, respectively, in each period. The change in final demand thus calculated in each period is treated as an exogenous policy shock given to the general equilibrium system in the next period in our model.

Consumer Surplus: Smith and Kaoru summarized about 200 econometric studies of recreation demand in the literature into eight representative models. This study uses model eight of Smith and Kaoru to calculate policy effects in terms of change in real consumer surplus for each of the three recreation activities in the model. Aggregate consumer surplus in each period is calculated by multiplying the total number of trips by per-trip consumer surplus derive from model eight in Smith and Kaoru.

3. Combining CGE Model with Recreation Demand Model

The following steps are followed in each period to generate the continuous benchmark path. The first step is to calculate static general equilibrium solutions for each period given the updated values of labor and capital from previous period. The second step is to calculate per capita real income and population for the period using the CGE model results of the corresponding period. The third step is to calculate total number of trips for the recreation activities using the results from the second step above. The fourth step is to transform the total number of trips into the recreation-related expenditure for trade sector and services sector. The fifth step is to calculate aggregate consumer surplus using the recreation demand model (model 8, Smith and Kaoru) with the total number of trips given by the third step.

The following steps are followed in each period to generate the continuous counterfactual path. The first step is to calculate static general equilibrium solutions for each period given (i) the updated values of labor and capital from previous period , (ii) the reduced land use in agricultural sectors and increased water acreage at wetlands, and (iii) the increase in final demand for the recreation-related sectors, which is calculated in sixth step below. The second, third, fourth, and fifth steps are the same as those for the continuous benchmark. The sixth step is to calculate the difference between the continuous benchmark and counterfactual values of the recreation-related expenditures in the two sectors. This difference is treated as an exogenous shock to the next period's general equilibrium system (the first step above).

Data and Calibration

We used IMPLAN to make a SAM for Churchill County, Nevada. The 528 sectors in the Churchill SAM are aggregated into the eight sectors. Elasticities used in our model are from various econometric studies and from previous CGE studies. To calibrate the model, non-elasticity parameters were solved for given base-year values of the model variables, values of elasticities, and the particular functional forms for the model.

Analysis of the Results

The terminal period was set at the sixth year. Policy effects are evaluated by comparing continuous counterfactual solutions with continuous benchmark solutions. The impact of transferring 125,000 acre-foot of water from agricultural sectors to wetlands was examined.

Table 2 shows the impact of the surface water reallocation on the agricultural sectors and non-agricultural sectors. Each of the numbers in the table represents sum of the stream of outputs over a 6-year period . Total output in the agricultural sectors drops by $95.13 million or a 30.07 percent decrease as compared to the continuous benchmark. Total output in the non-agricultural sectors increases by $5.8 million or a 0.17 percent increase as compared to the continuous benchmark. For the entire Churchill County economy, total output decreases by $89.72 million or only 2.43 percent decrease compared to the continuous benchmark.

Table 3 shows that because of the reduction in outputs in agricultural sectors, labor is released from the sectors. The released labor is either employed by the non-agricultural sectors (Table 3) or out-migrates to the ROW. The released labor going to the non-agricultural sectors increases the supply of labor in the non-agricultural sectors, increasing non-agricultural employment and outputs. This increase in labor supply in non-agricultural sectors coupled with decrease in labor demand in agricultural sectors due to the policy shock lower the wage rates in the economy when compared to the continuous benchmark, which causes some of the released labor to out-migrate to ROW.

Table 4 shows that the total number of trips increases over time for both continuous benchmark and counterfactual because of the increase in population over time. Also, as policy is implemented, the total number of trips is larger for continuous counterfactual than for continuous benchmark. This is explained by increase in the acreage at the wetlands compared to the continuous benchmark.

The total increase in final demand for the recreation-related sectors over a six-year period is $6.71 million, which is only 7.05 percent of the reduction in agricultural output due to the water reallocation policy. The increase in these recreation-related expenditures is so small that it can not compensate for the decrease in agricultural outputs. We also calculated change in consumer surplus from the increased recreation activities using the number of trips calculated in each period. The total increase in the sum of the stream of the present discounted values (PDVs) of consumer surplus is 16.1% compared to the continuous benchmark.

Table 7 shows the sum of the stream of the PDVs of per capita incomes and per capita consumer surplus from recreation activities for continuous benchmark and counterfactual, respectively. The sum of the stream of the PDVs of per capita income decreased from $78,727 in continuous benchmark to $77,337 in continuous counterfactual, a decrease of $1390 over a six-year period. The sum of the stream of the PDVs of per capita consumer surplus for all categories of recreation activities increased from $15.61 in continuous benchmark to $18.08 in continuous counterfactual, an increase of $2.47, over a six-year period. This increase in the sum of the stream of the PDVs per capita consumer surplus for recreation activities is far less than the decrease in per capita income. Therefore, according to this study, the water reallocation policy reduces the total welfare of the residents of Churchill county.

Conclusion

Traditional analyses of water reallocation policy focus either on their economic impacts or on welfare change from increased use of water as a public good, but not on both. The dynamic CGE model combined with a recreation demand model used in this study provides a framework in which the effects of a water reallocation policy are evaluated over time not only in terms of its economic impacts but also in terms of the welfare change from increased recreation activities. The model results show that per capita increase in consumer surplus due to increased recreation activities is far less than the reduction in per capita income of the residents of Churchill County. It is concluded that water reallocation policy reduces the total welfare of the residents of Churchill County.

The limitation of this research is that the present model cannot fully capture the effects of water reallocation policy which spill over to regions outside of Churchill County and the feedback effects coming from those surrounding regions. To capture these interregional interactions, we plan to extend the present model to a multiregional model.

Table 1. Seemingly Unrelated System of Participation Equations for the Stillwater National Wildlife Refuge.

	Δ log(angling)[a]	Δ log(recreation)[a]	Δ log(hunting)[a]	Ducks
Constant	438.88	21.407	-1335.6	710.32
	(618.40)	(292.26)	(488.3)	(452.81)
Acres	0.0195	-0.001	0.004**	0.044*
	(0.0164)	(0.006)	(0.010)	(0.016)
ΔPopulation	-7.571	6.252	59.678**	
	(35.674)	(16.428)	(27.377)	
ΔIncome	10.273	-3.940	16.749	
	(15.835)	(7.297)	(12.161)	
Ducks		0.026	0.236*	
		(0.068)	(0.120)	
Standard Error	0.88	0.42	0.70	1244.00
System R^2		0.30		

* significant at the 10% level

** significant at the 5% level

[a] coefficients multiplied by 1,000 for presentation

Table 2. Impacts of Reallocation of Surface Water on Outputs in Agricultural and Non-agricultural Sectors Over a Six-Year Period

Sector	Continuous Benchmark ($1,000,000)	Continuous Counterfactual ($1,000,000)
Agricultural Sectors (Total)	316.4	221.3
Non-agricultural Sectors (Total)	3370.7	3376.5
Total	3687.1	3597.8

Table 3. Impacts of Reallocation of Surface Water on Employment in Agricultural Sectors and Non-agricultural Sectors Over a Six-Year Period

Sector	Continuous Benchmark	Continuous Counterfactual
Agricultural Sectors (Total)	2717	1945
Non-agricultural Sectors (Total)	146676	147050
Total	149393	148995

- The unit of labor in this table is scaled such that one unit of labor earns $10,000 in base year.

Table 4. Impacts of Reallocation of Surface Water on Total Number of Trips for Recreation Activities

	year 1	*year 2*	*year 3*	*year 4*	*year 5*	*year 6*
Continuous Benchmark	26845	29408	33326	39658	50400	69372
Continuous Counterfactual	27859	31643	36221	43838	57025	80634

Table 5. Sum of PDVs of Per Capita Income and Per Capita Consumer Surplus from Recreation Activities Over a Six-Year Period

(in Dollars)

		Continuous Benchmark	Continuous Counterfactual	Change
Per Capita Income		78,727.892	77,337.821	-1,390.07
Recreation Benefits	Angling	2.568	3.518	0.95
	General Recreation	7.392	7.382	-0.01
	Hunting	5.653	7.184	1.531
Recreation Total		15.613	18.084	2.471

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