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# **Economic impacts of surface water reallocation policies: A comparison of supply-determined SAM and CGE models**

**Chang K. Seung, Thomas R. Harris, and Thomas R. MacDiarmid**

University of Nevada, Reno

**Abstract.** This study analyzes the economic impacts of transferring surface water from irrigated agriculture to recreational use at the Stillwater National Wildlife Refuge in Churchill County, Nevada. The study employs two alternative regional economic models: a supply-determined social accounting matrix (SDSAM) model and a regional computable general equilibrium (CGE) model. Model results show that the SDSAM model overestimates the policy impacts on output and factor income in agricultural sectors compared to the CGE model. We contend that a regional CGE model is theoretically more appropriate than a SDSAM model for an impact analysis where productive capacity of rural sectors is reduced.

## **1. Introduction**

Water reallocation issues are important in the western United States. A rich literature exists on the tradeoffs from various water policies among alternative water users. Numerous state and regional economic impact studies of water management in the western states have been conducted. Classic examples of state-specific impact studies are Seckler (1971) and Kelso *et al.* (1973). Other examples include the Pacific Northwest economic evaluation of irrigation development and hydroelectric power generation (Hamilton *et al.* 1982; Hamilton and Pongtanakorn 1983).

More recently Dinar and Zilberman (1991) model interaction between agricultural drainage salinity and the regional cropping and economic impacts in the San Joaquin Valley of California using an integrated economic/engineering approach. Berck *et al.* (1992) employ computable general equilibrium (CGE) procedures to investigate the reallocation of water in the San Joaquin Valley, and Leones *et al.* (1997) investigate the economic impacts of recreation in the Rio Grande River Basin near Taos, New Mexico.

Another emerging issue is the regional economic tradeoff between the use of water for wetland preservation and the out-of-stream use for irrigated agriculture. The Stillwater National Wildlife Refuge is located in Churchill County, Nevada, about 80 miles east of Reno. The amount of water received by these wetlands has been highly variable between high water and drought years and is expected to decline in normal water years as a result of proposed changes in water allocation under the Bureau of

Table 1. Output and employment by industry in Churchill County, 1992

Sectors	Output		Employment	
	(\$ million)	(%)	(jobs) <sup>1</sup>	(%)
Livestock	26.37	4.6	575	6.0
Other crops	3.54	0.6	107	1.1
Hay and pasture	9.49	1.7	86	0.9
<i>Agricultural Total</i>	39.40	6.9	768	8.0
Mining	23.82	4.1	55	0.6
CMTCPU <sup>2</sup>	127.54	22.4	1089	11.3
Trade	58.49	10.3	1731	17.9
FIRE <sup>3</sup>	65.59	11.5	505	5.2
Services	169.68	29.7	2825	29.3
Federal government	65.57	11.5	1619	16.7
State and local government	20.36	3.6	1063	11.0
<i>Nonagricultural total</i>	531.05	93.1	8887	92.0
TOTAL	570.45	100.0	9655	100.0

<sup>1</sup>Full-time and part-time jobs

<sup>2</sup>CMTCPU denotes construction, manufacturing, transportation, communication, and public utilities.

<sup>3</sup>FIRE denotes finance, insurance, and real estate

Source: Output in agricultural sectors is based on 1995 *Nevada Agricultural Statistics* and 1992 IMPLAN. Output in nonagricultural sectors is from 1992 IMPLAN. Employment in agricultural sectors is based on 1992 *Regional Economic Information System* (REIS) and 1992 IMPLAN data. Employment in mining sector is from 1991 REIS data. Employment in the other nonagricultural sectors is from 1992 REIS data

Reclamation's (BOR) operating criteria and procedures (OCAP) for the Newlands reclamation project. Water quality samples indicate high concentrations of arsenic, selenium, boron, lead, and mercury, in addition to total dissolved solids. Thus, the quality and quantity of water received by wetlands have become issues of concern as they impact the economy of the area.

The Stillwater wetlands consist of many diverse reservoirs, marshes, ponds, ditches, and sloughs that provide over 200,000 acres of habitat for fish, upland game, and migratory fowl. The Stillwater National Wildlife Refuge and surrounding wetlands form the largest bird sanctuary in Nevada (Oleson 1989). The wetlands are located along the Pacific Flyway, providing a feeding and resting area for about 30 percent of western America's migrating waterfowl. During the high water year of 1985 Stillwater had an estimated 14,000 acres of wetlands. But during recent drought years the wetlands area declined to between 3,000 and 4,000 acres. This situation has caused a significant deterioration in the quality of the wetlands. An evaluation of programs to reverse this process is important to policy makers.

The Stillwater wetlands also support varied recreational activities, including angling, wildlife observation, waterfowl hunting, and camping. Estimated visits to Stillwater range from 28,000 to 40,000 visits annually. These visits generate expenditures of more than \$1.1 million, which translates into an additional \$440,000 of direct and indirect income to Churchill County (Loomis 1985).

Table 1 presents output and employment by production sectors for 1992. Total agricultural output in the Churchill County economy in 1992 is about \$39.40 million or about 6.9 percent of the economy's total output of \$570.45 million. Major agricultural sectors are the livestock, other crops, and hay sectors which produce

about 4.6 percent, 0.6 percent, and 1.7 percent of the economy's total output, respectively (Table 1). Total nonagricultural output in the economy in 1992 is about \$531.05 million or about 93.1 percent of the economy's total output. The largest nonagricultural sector is the services sector which produces about \$169.68 million of output or about 29.7 percent of the total output in the economy. Table 1 also divides employment by sector.

Transferring water from irrigated agriculture to wetlands will reduce agricultural production and increase water-related recreation activities. There are several ongoing policy efforts to increase water supplies to the wetlands, particularly through acquisition of agricultural water rights. Also, policy makers are interested in the economic impacts of such public policy. There has been no effort to investigate the impacts of alternative surface water allocations on the rural economy of Churchill County.

Input-output (I-O) and social accounting matrix (SAM) models typically have been used for impact analyses. Changes in final demand, an exogenous variable, are estimated, and the effects of these changes on the economy are calculated. There is, however, a special case of impact analysis where the productive capacity of a sector is curtailed or eliminated. Based upon Miller and Blair (1985, Chapter 9), regional economists often have used mixed exogenous/endogenous I-O models in which final demands for some sectors and gross outputs for the remaining sectors are specified exogenously. They have used the mixed exogenous/endogenous I-O model in situations where the productivity capacity of a sector is exogenously reduced (e.g., Petkovich and Ching 1978). Recently SAM versions of the mixed exogenous/endogenous model, so-called *supply-determined SAM (SDSAM) models*, have been developed to examine the impact of timber production potentials on income distribution (Marcouiller *et al.* 1993) or to analyze the effects of public land grazing reductions on urban and rural northern Nevada (Harris *et al.* 1996). Although these mixed exogenous/endogenous models are relatively easy to implement, they have several limitations that a fixed price model faces (represented by fixity of prices and no factor substitution in production and no commodity substitution in consumption).

The present study examines the economic impacts of transferring surface water from agricultural sectors to the wetlands. We employ two alternative regional economic models, a SDSAM model and a regional computable general equilibrium (CGE) model. We first use a SDSAM model in which outputs of agricultural sectors are exogenously determined by water withdrawal and all the prices including factor prices are assumed to be fixed. To overcome the limitations of the SDSAM model, we then use a regional CGE model in which output in all the sectors are endogenously determined and the prices are flexible enough to clear the goods and factor markets. Model results from the two alternative regional impact models are compared. We contend that a regional CGE model is theoretically more sound than a mixed exogenous/endogenous fixed price model for an impact analysis where the productive capacity of rural sectors is reduced.

## 2. Model specification

There are several features and assumptions commonly employed in the two alternative models. In each of the two models there are eight production sectors. Three are agricultural sectors: (i) livestock, (ii) other crops, and (iii) hay and pasture. The other five sectors are nonagricultural sectors which include (iv) mining, (v) construction, manufacturing, transportation, communication, and public utilities (CMTCPU), (vi) trade, (vii) finance, insurance, and real estate (FIRE), and (viii) services. Intermediate inputs are used in each of the two models. There are three categories of factor income—labor income, capital income, and land income (for agricultural sectors only)—and one enterprise account in each of the models. In each of the models households are categorized into three groups following the IMPLAN (IMPact Analysis for PLANning) database (Alward *et al.* 1992): low income households, medium income households, and high income households.

In each of the two models in our study the recreation-related sectors are the trade sector and the services sector. When there is an increase in water acreage at the wetlands due to water reallocation, there will be increases in expenditures for these two sectors. These increases in expenditures have two sources: first, increases in expenditures by nonlocal visitors, defined as the visitors who live outside Churchill County, and second, increases in expenditures by local visitors, defined as the visitors who live within the Churchill County. Expenditures by nonlocal visitors bring new dollars into a local economy and stimulate economic activity as suggested by export base theory; i.e., recreational services are being exported (Alward *et al.* 1985; Bergstrom *et al.* 1996; English and Bergstrom 1994; Miller and Blair 1985; Palmer and Siverts 1985). Thus, impacts in an economy attributable to recreation can be traced to spending by these visitors for recreation and related services. Each of the two impact models in this study treats the increases in expenditures by nonlocal visitors as exogenous shock. For expenditures by local visitors the models assume that increased recreational spending by local visitors due to increased water acreage at the Stillwater wetlands comes at the expense of reduced recreational spending elsewhere in Churchill County (*displacement effect*). In other words, it is assumed that there is no net change in total recreational spending made by local visitors.

### 2.1 SDSAM model

I-O techniques have been fundamental to regional economic analysis for the past half century (Richardson 1985; Miller and Blair 1985; Rose and Miernyk 1989). Extending I-O analysis to a SAM analysis has been a more recent phenomenon. This extension has resulted from dissatisfaction with both the nature of I-O analysis and its incomplete measure of distributive impacts. (Pyatt and Round 1985; Kuening and deRuijter 1988). During the 1980s SAMs have been used to more fully analyze regional economic development (Eckaus *et al.* 1981; Cohen 1988; Skountzos 1988), including the effects on income distribution (Adelman and Robinson 1986; Havinga *et al.* 1987; Marcouiller *et al.* 1993).

Following procedures outlined by Holland and Wyeth (1989), the SAM model can be represented as:

$$\begin{bmatrix} X \\ V^* \\ Y^* \end{bmatrix} = (I - S)^{-1} \begin{bmatrix} ex \\ ev \\ ey \end{bmatrix} \quad (1)$$

where:

- $X$  = A vector of sectoral output;
- $V^*$  = A vector of value added by categories;
- $Y^*$  = A vector of household incomes;
- $I$  = The identity matrix;
- $S$  = A matrix of direct SAM coefficients;
- $ex$  = A vector of exogenous final demand;
- $ev$  = A vector of exogenous value added; and
- $ey$  = A vector of exogenous household income.

Here, the matrix of direct SAM coefficients,  $S$ , is

$$S = \begin{bmatrix} A & O & C \\ V & O & O \\ O & Y & H \end{bmatrix} \quad (2)$$

where:

- $A$  = A matrix of input-output coefficients;
- $V$  = A matrix of value-added coefficients;
- $Y$  = A matrix of value-added distribution coefficients;
- $C$  = A matrix of expenditure coefficients; and
- $H$  = A matrix of institutional and household distribution coefficients.

Also,  $(I - S)^{-1}$  represents the matrix of SAM coefficients. Endogenous accounts that pertain to the SAM constructed in equation (1) include production sectors, value added, and institutional accounts that include enterprise and various types of households. Exogenous accounts are those accounts specified as government, capital, and the rest of the world. Injections to the system include transfers to institutions and to households from government and the rest of the world. In addition, injections occur through demands of production activities from government, investment, and exports to the rest of the world. Leakages included taxes, savings, and imports.

The SDSAM approach is adapted from the mixed endogenous-exogenous version of the I-O model (Miller and Blair 1985, Chapter 9) and applied to the SAM model as developed by Schreiner and Garcia (1992), Marcouiller *et al.* (1993), and Marcouiller *et al.* (1995) such that gross output for the supply-determined sectors and final demands for remaining sectors are specified exogenously.

Suppose that there are  $n$  production sectors, a value added account, and a household account in the economy. Suppose further that the first  $k$  sectors' outputs are

supply determined. Then, following procedures as described by Miller and Blair (1985) and Marcouiller *et al.* (1995), the SDSAM model can be expressed as:

$$Z = B^{-1}W \quad (3)$$

where:

$$Z = \begin{bmatrix} ex_1 \\ ex_2 \\ \vdots \\ ex_k \\ X_{(k+1)} \\ X_{(k+2)} \\ \vdots \\ X_n \\ V^* \\ Y^* \end{bmatrix},$$

$$B = \begin{bmatrix} -1 & 0 & \cdots & 0 & -S_{1(k+1)} & -S_{1(k+2)} & \cdots -S_{1n} & -S_{1v} & -S_{1y} \\ 0 & -1 & \cdots & 0 & -S_{2(k+2)} & -S_{2(k+2)} & \cdots -S_{2n} & -S_{2v} & -S_{2y} \\ \vdots & \vdots & & \vdots & \vdots & \vdots & & \vdots & \vdots \\ \vdots & \vdots & & \vdots & \vdots & \vdots & & \vdots & \vdots \\ 0 & 0 & \cdots & -1 & -S_{k(k+1)} & -S_{k(k+2)} & \cdots -S_{kn} & -S_{kv} & -S_{ky} \\ 0 & 0 & \cdots & 0 & (1 - S_{(k+1)(k+1)}) & -S_{k(k+1)(k+2)} & \cdots - & -S_{(k+1)v} & -S_{(k+1)y} \\ \vdots & \vdots & & \vdots & \vdots & \vdots & S_{(k+1)n} & \vdots & \vdots \\ 0 & 0 & \cdots & 0 & -S_{y(k+1)} & -S_{y(k+2)} & \cdots -S_{yn} & -S_{yv} & (1 - S_{yy}) \end{bmatrix}$$

and

$$W = \begin{bmatrix} -(1-S_{11})X_1 + S_{12}X_2 + \dots + S_{1k}X_k \\ S_{21}X_1 - (1-S_{22})X_2 + \dots + S_{2k}X_k \\ \vdots \quad \quad \quad \vdots \quad \quad \quad \vdots \\ S_{k1}X_1 + S_{k2}X_2 + \dots + (1-S_{kk})X_k \\ S_{(k+1)1}X_1 + S_{(k+1)2}X_2 + \dots + S_{(k+1)k}X_k + ex_{(k+1)} \\ \vdots \quad \quad \quad \vdots \quad \quad \quad \vdots \quad \quad \quad \vdots \\ S_{n1}X_1 + S_{n2}X_2 + \dots + S_{nk}X_k + ex_n \\ S_{v1}X_1 + S_{v2}X_2 + \dots + S_{vk}X_k + ev \\ S_{y1}X_1 + S_{y2}X_2 + \dots + S_{yk}X_k + ey \end{bmatrix}$$

where:

$S_{ij}$ s = The elements of matrix S;  
 $X_1, X_2, \dots, X_k$  = Exogenous variables denoting output levels of the supply-determined sectors;

$ex_{k+1}, ex_{k+2}, \dots, ex_n, ev, ey$  = Exogenous final demand variables; and

$ex_1, ex_2, \dots, ex_k, X_{k+1}, X_{k+2}, \dots, X_n, V^*, Y^*$  = Endogenous variables.

In our study the sectors whose output levels are reduced exogenously are agricultural sectors that include the livestock, other crops, and hay and pasture sectors. Sectoral final demand changes are the increased expenditures in recreation-related sectors from increased wetlands tourism. The recreation-related sectors in this study are the trade sector and the services sector. In our SDSAM model we treat as exogenous shocks the decrease in the agricultural outputs and the increase in the final demand for the recreation-related sectors.

To calculate the policy impacts on incomes for factors of production in agricultural sectors in our study we first calculate the impacts on the total value added—i.e., the sum of employee compensation, proprietors' income, and other property income—for each of the agricultural sectors. Then we use factor shares developed by Robinson *et al.* (1990) to allocate the change in total value added to change in income for each factor of production for each agricultural sector. In deriving the change in nonagricultural factor income we treat the change in employee compensation as a change in labor income and the change in combined proprietors' income and other property income as a change in capital income.



## 2.2 Churchill County CGE Model

Although the SDSAM model is appropriate for addressing income distribution issues and is relatively easy to implement, the model lacks important microtheoretic foundations by assuming fixed prices and ignoring substitution effects in use of factor inputs and in consumption of final products. In contrast, CGE models are based on the Walrasian general equilibrium structure. In CGE models prices are endogenously determined and substitution is allowed in production and in consumption. Because the CGE model allows prices to be determined endogenously, it enables analysts to examine the welfare implications of a policy change. This section describes major features of our CGE model for Churchill County.

### 2.2.1 Production

Production technology in each sector is represented by a Cobb-Douglas (CD) value-added function. A constant returns to scale technology is assumed for each sector's production. Intermediate inputs are used in fixed ratios. Agricultural sectors use labor, capital, and land as primary production inputs. Nonagricultural sectors use only labor and capital as primary factors of production. The production technology in agricultural sectors is represented by

$$X_i = \Phi_i L_i^{\alpha} K_i^{\kappa} N_i^{\eta} \quad (4)$$

where:

- $X_i$  = Output in an agricultural sector  $i$ ;
- $\Phi_i$  = The shift parameter;
- $L_i$ ,  $K_i$ , and  $N_i$  = Labor, capital, and land used in the sector, respectively; and
- $\alpha_i$ ,  $\kappa_i$ , and  $\eta_i$  = Labor, capital, and land income shares in the sector, respectively.

A fixed amount of water is combined with a unit of land in agricultural sectors for production. Thus, withdrawal of a certain amount of water from agricultural sectors implies reduction of land use in the sectors, increasing the returns to land in the sectors. In our CGE model the exogenous shock is initially given to land use in the agricultural sectors and factor substitution is allowed when land use is reduced. This is not the case in our SDSAM model where the initial shock is given to levels of agricultural outputs and factor substitution is not allowed.

### 2.2.2 Consumption

Preferences of the households are represented by a constant elasticity of substitution (CES) utility function. Each type of household is assumed to consume locally produced goods and imported goods from outside Churchill County. Utility maximization for each type of household subject to its budget constraint yields its demand function for each good:

$$C_{ih} = \frac{\beta_{ih} \text{HEXP}_h}{PQ_i^{\lambda_h} \sum_j \beta_{jh} PQ_j^{(1-\lambda_h)}} \quad (5)$$

where:

- $C_{ih}$  = Quantity of good  $i$  consumed by household type  $h$ ;
- $\beta_{ih}$  = Share parameter for good  $i$  and household  $h$ ;
- $\text{HEXP}_h$  = Household  $h$ 's total expenditure on goods;
- $PQ_j$  = Price of good  $j$  which is a composite of locally produced and imported versions; and
- $\lambda_h$  = Household  $h$ 's elasticity of substitution for goods.

### 2.2.3 Factor markets and mobility

Profit maximization for each sector's production yields its demand function for each factor of production. The supply of labor has two sources—labor from inside the region and the labor from outside the region, i.e., labor immigration. It is assumed that labor is mobile across sectors such that sectoral distribution ratios of wage rates are maintained. Labor is incompletely mobile between the study region and the rest of the world (ROW) depending on the interregional differentials in wage rates. Thus, the net migration of labor into Churchill County is determined as follows:

$$\text{LMIG} = \text{LSTK} \left[ \left( \frac{\text{WAVG}}{\text{WROW}} \right)^{\text{LME}} - 1 \right] \quad (6)$$

where:

- $\text{LMIG}$  = The net immigration of labor;
- $\text{LSTK}$  = The aggregate stock of labor given in the base year;
- $\text{WAVG}$  and  $\text{WROW}$  = Average wage rates in Churchill County and in the rest of the world, respectively; and
- $\text{LME}$  = The labor migration elasticity.

Physical capital is fixed in each sector and is immobile both intersectorally and interregionally. Land in each agricultural sector is fixed at the base year level before policy implementation and at the reduced level with the policy.

## 3. Empirical implementation

This section discusses results from the SDSAM and the CGE model scenarios where there is 125,027 acre-feet of water inflow to the Stillwater National Wildlife Refuge wetlands. This amount of inflow will be met with the acquisition of 101,000 acre-feet of water rights from agricultural producers and drainage from remaining irrigated acreage (MacDiarmid 1988; Harris *et al.* 1998). The reduction in agricultural land use due to withdrawing water from agriculture is about 51.20 percent compared to the base year.

### 3.1 Data

The IMPLAN database for 1992 is used to make a SAM for Churchill County, Nevada that is used for both the SDSAM and CGE models. The 528 sectors in the Churchill SAM are aggregated into the eight sectors in this study using a method similar to the one used in Kraybill and Pai (1995). Table A.1 and Table A.2 in the appendix describe the structures of Churchill County SAM and 1992 Churchill SAM, respectively. Table A.3 describes sector aggregation scheme for the present study. Elasticities used in the CGE model are from previous econometric studies and are presented in Table A.4. To calibrate the CGE model, nonelasticity parameters are solved for given base year values of the model variables, values of elasticities, and the particular functional forms for the model equations. Incomes of the three types of households are designated by IMPLAN software where low income households earn less than \$20,000; medium income households earn between \$20,000 and \$40,000; and high income households earn more than \$40,000 (Alward *et al.* 1992). To calculate base year factor income in each of the agricultural sectors for each of the two models we use factor shares developed by Robinson *et al.* (1990). For nonagricultural sectors we treat employee compensation as labor income and the combined proprietors' income and other property income as capital income for each of the two alternative models.

For data on water available in agricultural sectors and at the wetlands after the policy implementation we use the information in Harris *et al.* (1998). The authors find that with the acquisition of 101,000 acre-feet of water rights from agricultural production, the water available in the agricultural sectors would decline from 197,280 acre-feet and 53,319 irrigated acres to 96,280 acre-feet and 26,022 irrigated acres. The inflow to the wetland would increase from 88,945 acre-feet to 125,027 acre-feet due to the policy. Details are found in Table A.5 in the appendix or in Harris *et al.* (1998).

With the reallocation of surface water to the wetlands, tourism expenditures by recreation visitors would increase because the surface area of the wetlands will increase. Using a general population mail survey of Nevada residents Harris *et al.* (1998) estimate the relationship between the numbers of trips by angling, general recreation, and hunting visitors and the water supply to the Stillwater National Wildlife Refuge wetlands using a seemingly unrelated regression (SUR) method. The authors find that the size of water acreage at Stillwater National Wildlife Refuge has a positive influence on number of recreators in hunting and angling. Details are found in Harris *et al.* (1998).

The general population survey of Nevada residents also reveals expenditure patterns by Nevada residents who travel to the Stillwater Wildlife Area as derived by Harris *et al.* (1998). The authors find that per trip expenditure is an estimated \$45.50 for gasoline, food, and supplies. This value is margined at 25.5 percent (Fletcher *et al.* 1997). The margined value is calculated to be about \$11.60, which is the amount of expenditure for gasoline, food, and supplies that remains in the Churchill County economy. Per trip expenditure for lodging is \$12.50. Therefore, per trip total expenditure that remains in the Churchill County economy is estimated at \$24.10. In our

study the expenditures for gasoline, food, and supplies are allocated to the trade sector and the expenditure for lodging is allocated to the services sector. Thus, with the increase in trip activity from 125,027 acre-feet of water inflow to the wetlands, Churchill County trade sector expenditures increase \$1,740 while Churchill County services sector expenditures increase \$1,875. These increases in expenditures are small compared to the size of the Churchill economy; the total increase in expenditure on the recreation-related sectors of \$3,615 is only 0.0006 percent of base year level of the total value of production in the Churchill County economy. Therefore, the increases in the recreation-related expenditures are not expected to generate noticeable economic impacts in each of the two alternative models.

### 3.2 Analysis of the model results

Given the decrease in agricultural output and the increased local expenditures for the trade sector and the services sector, an analysis of the economic impacts from the transfer of surface water from irrigated agriculture to recreation are calculated by employing the SDSAM and the regional CGE model.

Results from employing the two alternative models to estimate impacts of reallocation of surface water in Churchill County are shown in Tables 2 and 3. Table 2 shows that output in each of the agricultural sectors decreases about 51.20 percent with the SDSAM model. But the CGE model predicts smaller impacts on agricultural outputs: compared to the base-year output levels, the outputs of the livestock, other crops, and hay and pasture sectors decrease about 35.70 percent, 35.15 percent, and 35.88 percent, respectively. In a CGE model factor substitutions are allowed in agricultural production, while no factor substitution is allowed in the SDSAM model.

Table 2 also shows that the policy impacts on nonagricultural sectors' output differ depending on the model used. The SDSAM model predicts that the policy reduces outputs of all the nonagricultural sectors. But the CGE model results indicate that there will be an increase in output in three of the five nonagricultural sectors: the mining, CMTCPU, and services sectors. As Table 2 shows, the total nonagricultural output with the SDSAM model decreases about 2.04 percent while it increases about 0.71 percent with the CGE model. The increases in the nonagricultural outputs in the CGE model are caused by the inflow of labor from agricultural sectors. In other words, as output is reduced in agricultural sectors, labor is released from the sectors. The released labor is either employed by some of the nonagricultural sectors or outmigrates to the rest of the world. The released labor going to those nonagricultural sectors in the region increases the supply of labor, increasing employment and output, in the nonagricultural sectors—mining, CMTCPU, and services (Tables 2 and 3). This increase in labor supply in the nonagricultural sectors coupled with a decrease in labor demand in agricultural sectors due to the policy shock lowers the average wage rate in the economy about 1.32 percent compared to the base year. This causes more labor to be released from the agricultural sectors and labor that had been employed in the nonagricultural sectors to outmigrate. The labor outmigration calculated by our CGE model is estimated to be 120 jobs. The total output in the econ-

Table 2. Impacts of water reallocation

	SDSAM model (in \$ million)	CGE model (in \$ million)
<b>Panel A: Output</b>		
Livestock	-18.08 (-51.20%)	-12.61 (-35.70%)
Other crops	-2.44 (-51.20%)	-1.67 (-35.15%)
Hay and pasture	-6.46 (-51.20%)	-4.52 (-35.88%)
<i>Total agricultural output</i>	-26.97 (-51.20%)	-18.81 (-35.69%)
Mining	-0.08 (-0.34%)	0.45 (1.81%)
CMTCPU <sup>1</sup>	-2.98 (-2.45%)	1.77 (1.45%)
Trade	-1.98 (-3.62%)	-0.45 (-0.82%)
FIRE <sup>2</sup>	-2.68 (-4.22%)	-0.20 (-0.31%)
Services	-3.02 (-1.15%)	2.19 (0.83%)
<i>Total nonagricultural output</i>	-10.75 (-2.04%)	3.75 (0.71%)
<b>TOTAL OUTPUT</b>	-37.72 (-6.50%)	-15.05 (-2.59%)
<b>Panel B: Labor income</b>		
Livestock	-2.04 (-51.20%)	-1.41 (-35.24%)
Other crops	-0.53 (-51.20%)	-0.35 (-33.46%)
Hay and pasture	-1.02 (-51.20%)	-0.71 (-35.79%)
<i>Total ag labor income</i>	-3.60 (-51.20%)	-2.47 (-35.13%)
Mining	-0.02 (-0.33%)	0.11 (2.21%)
CMTCPU <sup>1</sup>	-0.85 (-2.45%)	0.33 (0.95%)
Trade	-0.90 (-3.63%)	-0.58 (-2.32%)
FIRE <sup>2</sup>	-0.33 (-4.22%)	-0.21 (-2.65%)
Services	-1.81 (-1.15%)	-0.53 (-0.34%)
<i>Total nonagricultural labor income</i>	-3.90 (-1.70%)	-0.87 (-0.38%)
<b>TOTAL LABOR INCOME</b>	-7.50 (-3.17%)	-3.34 (-1.41%)
<b>Panel C: Capital income</b>		
Livestock	-1.60 (-51.20%)	-1.09 (-35.23%)
Other crops	-0.41 (-51.20%)	-0.27 (-33.58%)
Hay and pasture	-0.79 (-51.20%)	-0.56 (-35.83%)
<i>Total ag capital income</i>	-2.80 (-51.20%)	-1.92 (-35.16%)
Mining	-0.02 (-0.31%)	0.11 (2.19%)
CMTCPU <sup>1</sup>	-0.44 (-2.25%)	0.19 (0.95%)
Trade	-0.22 (-3.57%)	-0.14 (-2.30%)
FIRE <sup>2</sup>	-1.09 (-4.22%)	-0.69 (-2.65%)
Services	-0.34 (-1.14%)	-0.10 (-0.34%)
<i>Total nonag capital income</i>	-2.10 (-2.45%)	-0.63 (-0.74%)
<b>TOTAL CAPITAL INCOME</b>	-4.90 (-5.36%)	-2.55 (-2.79%)
<b>Panel D: Land income</b>		
Livestock	-2.70 (-51.20%)	-1.86 (-35.24%)
Other crops	-0.70 (-51.20%)	-0.46 (-33.48%)
Hay and pasture	-1.35 (-51.20%)	-0.94 (-35.82%)
<b>TOTAL LAND INCOME</b>	-4.74 (-51.20%)	-3.26 (-35.14%)
<b>TOTAL FACTOR INCOME</b>	-17.13 (-5.08%)	-9.15 (-2.71%)
<b>Panel E: Enterprise income</b>		
	-2.12 (-10.60%)	-1.09 (-5.63%)
<b>Panel F: Household income</b>		
Low income household	-0.74 (-1.84%)	-0.49 (-1.22%)
Medium income household	-5.00 (-3.68%)	-3.57 (-2.62%)
High income household	-4.68 (-4.33%)	-3.42 (-3.15%)
<b>TOTAL HOUSEHOLD INCOME</b>	-10.42 (-3.67%)	-7.47 (-2.63%)

<sup>1</sup>CMTCPU denotes construction, manufacturing, transportation, communication, and public utilities<sup>2</sup>FIRE denotes finance, insurance, and real estate

omy decreases about 6.50 percent with the SDSAM model and about 2.59 percent with the CGE model (Table 2). Although not reported in this paper, this study finds that in the CGE model commodity prices in all nonagricultural sectors drop slightly because of the inward shift of the commodity demand curves due to reduced household income.

Table 2 also shows the policy impacts on factor income. The SDSAM model predicts larger impacts than the CGE model on both agricultural and nonagricultural factor income for each category of the factors. Total agricultural labor income with the SDSAM model decreases about 51.20 percent while it decreases about 35.13 percent with the CGE model. In the CGE model the reduced land use induces the agricultural sectors to substitute land for labor which results in smaller impacts on the agricultural labor income with the CGE model than with the SDSAM model. The policy impacts on the total nonagricultural labor income is greater with the SDSAM than with the CGE model. The total nonagricultural labor income with the SDSAM model decreases about 1.70 percent. Even though the total nonagricultural employment with the CGE model increases about 0.72 percent (Table 3), Table 2 shows that the total nonagricultural labor income with the CGE model decreases about 0.38 percent. This implies that in the CGE model the average wage rate in the nonagricultural sectors decreases because of the policy. The total labor income in the economy decreases about 3.17 percent with the SDSAM model while it decreases about 1.41 percent with the CGE model.

Total agricultural capital income decreases about 51.20 percent with the SDSAM model while it decreases about 35.16 percent with the CGE model (Table 2). Unlike the reduction in agricultural labor income, the reduction in agricultural capital income in the CGE model is due only to the decrease in returns to capital in the agricultural sectors with capital assumed fixed in each sector. In the CGE model the average return to capital in the agricultural sectors decreases about 35.14 percent compared to the base year. Total nonagricultural capital income with SDSAM model decreases about 2.45 percent while it decreases about 0.74 percent with the CGE model in which capital in each sector is assumed to be fixed. The average return to capital in nonagricultural sectors drops about 0.74 percent compared to the base year. In total the SDSAM model reports larger policy impacts on the total capital income in the economy (about 5.36 percent reduction) than the CGE model (about 2.79 percent reduction).

The CGE model reports smaller impacts on agricultural land income than the SDSAM model (Table 2). The agricultural land income decreases about 35.14 percent with the CGE model while it decreases about 51.20 percent with the SDSAM model. In the CGE model the reduction of land use in agricultural sectors is mitigated by the sharp increase in returns to land caused by the reduced supply of land in the sectors. The average return to land in the agricultural sectors rises about 33.00 percent compared to the base year. The total factor income in the economy is reduced about 5.08 percent with the SDSAM model while it is reduced about 2.71 percent with the CGE model.

Table 2 also describes the policy impacts on institutional income. The table shows that the CGE model reports smaller impacts on households' income than the

**Table 3.** Impacts of water reallocation on sectoral employment in Churchill County CGE model

	Benchmark solution (in jobs)	Counterfactual solution (in jobs)	% Change
Livestock	403	265	-34.24%
Other crops	75	50	-33.33%
Hay and pasture	60	39	-35.00%
<i>Total agricultural employment</i>	538	354	-34.20%
Mining	129	134	3.88%
CMTCPU <sup>1</sup>	1071	1096	2.33%
Trade	1519	1504	-0.99%
FIRE <sup>2</sup>	493	486	-1.42%
Services	5712	5768	0.98%
<i>Total nonag employment</i>	8924	8988	0.72%
<b>TOTAL EMPLOYMENT</b>	<b>9462</b>	<b>9342</b>	<b>-1.27%</b>

<sup>1</sup>CMTCPU denotes construction, manufacturing, transportation, communication, and public utilities

<sup>2</sup>FIRE denotes finance, insurance, and real estate

SDSAM model. This is an expected result because the CGE model predicts smaller impacts on income for each factor of production than the SDSAM model and the total factor income is distributed to households. Table 2 shows that total household income decreases about 2.63 percent with the CGE model and about 3.67 percent with the SDSAM model. With each of the two alternative models the household categories where most impacts occur are medium and high income households.

## 4. Conclusion

The conventional I-O or SAM models employ restrictive assumptions such as no factor substitution in production or commodity substitution in consumption and fixity of prices. These assumptions are not based upon modern neoclassical economic theory and are not plausible assumptions for a regional economy. These models tend to overestimate the impacts of a regional policy. The mixed exogenous/endogenous versions of these models such as mixed exogenous/endogenous I-O and SDSAM models employ more restrictive assumptions than the conventional I-O or SAM models. The mixed exogenous/endogenous versions are internally inconsistent because output for some sectors is forced to be fixed and final demands for the same sectors are assumed endogenous. Compared with these models, a regional CGE model is based firmly upon modern neoclassical economic theory and is capable of improving analysis of a regional economy.

In this paper we estimate the impact of transferring water from irrigated agriculture to the Stillwater Wildlife Refuge in Churchill County, Nevada. We employ two alternative models: a SDSAM model and a CGE model. Analyses of the model results show (i) that the SDSAM model predicts much larger impacts on agricultural production than does the CGE model, (ii) that the SDSAM model predicts decreases in output in all nonagricultural sectors while the CGE model reports increases in output in some of the nonagricultural sectors, and (iii) that the SDSAM model

reports larger impacts on both agricultural and nonagricultural factor income. This study indicates that compared with the CGE model, the SDSAM model overestimates the policy impacts and estimates production decreases in sectors where production may not change or may increase. This is due to SDSAM model restrictions on factor input and commodity consumption substitution. We conclude that a regional CGE model is theoretically more sound than a mixed exogenous/endogenous fixed price models for an impact analysis where productive capacity of rural sectors is curtailed or eliminated.

There are several limitations in this study. First, this study only encompasses the Churchill County area. The competitive impacts of expanded recreation on the Stillwater wetlands on other recreational areas in Nevada are not estimated in this study. A multicounty analysis could derive the recreational and agricultural impacts in areas outside Churchill County from a reallocation of surface waters in Churchill County. To address the policy effects generated outside of the region, an interregional CGE model may be required. Second, this study focuses on the economic impacts of water reallocation policies, ignoring the change in consumer welfare from change in recreation activities. For a more complete benefit-cost analysis, the current CGE analysis needs to incorporate a framework for measuring change in the consumer welfare from change in recreation activities.

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Appendix

Table A.1. Social accounting matrix for Churchill County CGE

	Production sectors	Value added	Enterprise	Household	Local govt	State govt	Federal govt	S-1	World
Production sectors	Intermediate inputs			Household purchase	Local govt purchase	State govt purchase	Federal govt purchase	Investment demand	Export
Value added	Value added								
Enterprise		Enterprise income							
Household		Household income from value added	Household income from enterprise		Govt transfer to households	Govt transfer to households	Govt transfer to households		
Local govt						State govt transfer	Federal govt transfer		
State govt	Indirect business tax				Local govt transfer		Federal govt transfer		
Federal govt	Indirect business tax	Social Security tax	Capital tax	Personal income tax					
S-1		Business savings	Household savings	Local govt savings	State govt savings				
World	Imports	Income leakage		Imports	Imports	Imports	Federal govt savings and imports	-(External savings) and imports	

Table A.2. Social accounting matrix for Churchill County 1992 (in millions of 1992 \$U.S.)

	Sector 1	Sector 2	Sector 3	Sector 4	Sector 5	Sector 6	Sector 7	Sector 8	Val 1	Val 2	Val 3
Sector 1	0.802	0.050	0.165	0.086	1.053	0.099	0.065	0.404			
Sector 2	1.285	0.101	0.223	0.001	0.109	0.017	0.044	0.077			
Sector 3	1.062	0.003	0.074	0.004	0.025	0.004	0.004	0.018			
Sector 4	0.019	0.002	0.016	1.572	2.124	0.018	0.012	0.107			
Sector 5	1.974	0.180	0.717	2.262	13.403	2.259	1.531	9.877			
Sector 6	0.832	0.055	0.239	0.289	4.084	0.520	0.128	1.633			
Sector 7	0.716	0.051	0.843	0.668	1.806	1.563	5.724	5.797			
Sector 8	0.473	0.087	0.170	1.164	6.236	4.032	3.875	20.243			
Val 1	3.052	1.009	0.445	5.163	34.547	24.825	7.767	157.129			
Val 2	3.641	0.825	0.426	0.818	2.752	1.822	0.294	15.628			
Val 3	5.672	1.378	5.296	4.065	16.822	4.259	25.566	13.823			
Ent.											19.969
HH 1									7.998	1.008	2.995
HH 2									75.980	9.071	15.975
HH 3									74.980	14.110	6.989
L-Gov.											
S-Gov.	0.313	0.020	0.322	0.430	1.461	4.562	6.276	2.574			
F-Gov.	0.216	0.014	0.222	0.295	1.004	3.316	4.315	1.770	18.995	2.016	
S-I											30.952
World	15.260	0.987	3.452	7.786	36.027	7.598	8.022	33.869	55.985		

Table A.2 (cont.) Social accounting matrix for Churchill County 1992 (in millions of 1992 \$U.S.)

	Ent.	HH 1	HH 2	HH 3	L-Gov.	S-Gov.	F-Gov.	S-I	World
Sector 1		0.237	0.606	0.284	0.061	0.143	0.056	0.384	30.821
Sector 2		0.069	0.150	0.063	0.007	0.016	0.000	0.005	2.596
Sector 3		0.011	0.029	0.013	0.003	0.007	0.003	0.018	11.333
Sector 4		0.046	0.118	0.055	0.012	0.029	0.011	0.852	19.608
Sector 5		5.658	14.478	6.751	1.559	3.637	1.579	9.837	45.748
Sector 6		5.908	18.907	10.462	0.074	0.173	0.031	1.178	10.202
Sector 7		8.049	22.287	10.759	0.320	0.746	0.034	0.575	3.684
Sector 8		11.705	30.799	13.741	4.740	11.060	66.396	21.041	67.188
Val 1									
Val 2									
Val 3									
Ent.									
HH 1	1.000				1.500	3.500	22.000		
HH 2	3.000				4.500	10.500	17.000		
HH 3	4.000				1.200	2.800	4.000		
L-Gov.						7.326	0.600		
S-Gov.					0.126		1.400		
F-Gov.	6.000	1.000	11.000	15.000					
S-I	5.969	-16.937	-27.413	20.004	-11.958	-35.944			
World		24.254	65.063	30.947	5.782	13.492	-52.043	-31.322	

Note: In this table, Val 1, Val 2, and Val 3 denote employee compensation, proprietors' income, and other property income, respectively; Ent. is enterprise income; HH1, HH2, and HH3 denote low income, medium income, and high income households, respectively; L-Gov., S-Gov., F-Gov. denote local, state, and federal government, respectively; and S-I denotes savings-investment account

**Table A.3.** Sector aggregation scheme for Churchill County CGE Model

IMPLAN sectors	Sectors in Churchill County CGE model
Sectors 1-9	Livestock
Sectors 10-12 and Sectors 14-27	Other crops
Sector 13	Hay and pasture
Sectors 28-47	Mining
Sectors 48-446	Construction, manufacturing, transportation, communication, and public utilities
Sectors 447-455	Trade
Sectors 456-462	Finance, insurance, and real estate
Sectors 463-528	Services

**Table A.4.** Elasticity values used in Churchill County CGE Model

Elasticities	Values
Elasticity of substitution in production (for all production sectors)	1.000 <sup>a</sup>
Elasticity of substitution in consumption <sup>b</sup>	
Low income households	0.750
Medium income households	1.125
High income households	1.500
Elasticity of substitution between imports and local goods <sup>c</sup>	
Livestock	1.420
Other crops	1.420
Hay and pasture	1.420
Mining	0.500
CMTCPU <sup>1</sup>	2.868
Trade	2.000
FIRE <sup>2</sup>	2.000
Services	2.000
Livestock	3.9
Other crops	3.9
Hay and pasture	3.9
Mining	2.9
CMTCPU <sup>1</sup>	2.9
Elasticity of transformation in production: domestic goods and exports <sup>d</sup>	
Trade	0.7
FIRE <sup>2</sup>	0.7
Services	0.7
Labor migration elasticity <sup>e</sup>	0.92

Source:

<sup>a</sup>Cobb-Douglas production function<sup>b</sup>The elasticities of substitution for low and high income households are from Shoven and Whalley (1984, p. 1011). We set the elasticity of substitution for medium income households at the average value of the elasticities for low and high income households<sup>c</sup>The elasticities of substitution for imports and local goods are based on de Melo and Tarr (1992, p. 231)<sup>d</sup>The elasticities of transformation are based on de Melo and Tarr (1992, p. 233)<sup>e</sup>The labor migration elasticity is from Plaut (1981)<sup>1</sup>CMTCPU denotes construction, manufacturing, transportation, communication, and public utilities<sup>2</sup>FIRE denotes finance, insurance, and real estate

**Table A.5.** Water and acreage available in agriculture and wetlands

	Base condition	Transfer condition
Diversion (A)	350,636 (acre feet)	350,636 (acre feet)
Transportation loss (B)	153,356 (acre feet)	153,356 (acre feet)
Water rights acquisition (C)	0 (acre feet)	101,000 (acre feet)
Farm delivery (D = A-B-C)	197,280 (acre feet)	96,280 (acre feet)
Farm delivery per acre (E)	3.7 (acre feet)	3.7 (acre feet)
Irrigated acreage (F = D/E)	53,319 (acre)	26,022 (acre)
Wetlands transfer rate (G) <sup>1</sup>	0.81	0.81
Wetlands delivery (H = G×C)	0 (acre feet)	81,619 (acre feet)
Drainage to wetlands (I)	88,945 (acre feet)	43,408 (acre feet)
Total wetlands inflow (J = H + I)	88,945 (acre feet)	125,027 (acre feet)

Source: MacDiarmid (1988) and Harris *et al.* (1998)

<sup>1</sup>Wetlands transfer rate of 0.81 is calculated as the use rate of 2.99 acre-feet per acre in agriculture divided by the farm delivery of 3.7 acre-feet per acre