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RANGELAND FIRES IN NORTHERN NEVADA: AN APPLICATION OF COMPUTABLE GENERAL EQUILIBRIUM MODELING[1]

by

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ABSTRACT

A dynamic computable general equilibrium model of a five county Northern Nevada economy is used to estimate the business losses and recovery efforts of a 1.6 million acre rangeland fire. In comparison to input-output or social accounting models, the dynamic computable general equilibrium model incorporates the roles of markets and prices in the estimation of this natural catastrophe. Results indicate that fire suppression and rehabilitation expenditures were not enough to offset the losses in public land grazing activities.

Introduction

In any natural disaster such as rangeland fire, drought, earthquake, etc., there is a need for immediate estimation of the monetary impacts. This impact information is used to initiate federal and state emergency programs as well as to provide information to private insurance companies. Federal agencies also use impact analysis to prioritize disaster relief funding and determine areas for additional assistance. These estimated impacts are also necessary for the formulation and development of mitigation plans that occur following a natural disaster.

During the summer of 1999, northern Nevada experienced its worst fire year with over 1.6 million acres of federal, state and private rangeland burned, which is approximately six percent (6%) of the total land in the five-county study area. Of the total acreage burned, private acreage burned was 131,963 acres or approximately eight percent of total burned rangeland acreage (U.S. Department of Interior). Lightning from thunderstorms was the primary cause of these late summer rangeland fires. At one point during the summer of 1999, more than 56 percent of the nation's federal fire fighting resources was involved in fighting these rangeland fires in Northern Nevada (U.S. Department of Interior).

The objective of this paper is to outline procedures to employ dynamic computable general equilibrium (CGE) modeling for estimation of impacts of natural disasters.

Specific objectives are to:

(1) To discuss previous economic impact studies of natural disasters,
(2) To present specifications of the model,
(3) To describe development and data for impact analysis, and
(4) To discuss application of dynamic CGE procedures for analysis of the 1.6 million rangeland fire.

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Previous Natural Disaster Impact Studies

Numerous studies have used inter-industry or economic procedures to estimate impacts of natural disasters. Ellison, et al. and Guimaraes, et al. used econometric models for analyzing the impacts of natural disasters. Gordon and Richardson employed a multi-regional interindustry model to estimate impacts of an earthquake. Rose, et al. derived direct and indirect effects of electricity lifelines disruptions from an earthquake using specially designed input-output and linear programming procedures. Cole employed social accounting matrix (SAM) approach to estimate the impacts of an earthquake.

However, input-output and social accounting models have some limitations. In these models, prices are fixed and there is no factor substitution in production or commodity substitution in consumption. Although these models are easy to implement, they tend to over estimate the impacts because of constant multipliers and unlimited supplies of inputs as implied by these models. Additionally, behaviors of firms and households are not estimated from constrained optimization. In contrast, CGE models are based on the Walrasian general equilibrium structure, which was formalized in the 1950's by Kenneth Arrow, Gerard Debreu, and others. CGE models explicitly incorporate supply constraints, identify prices and quantities separately, and have smooth, twice differentiable production and preference surfaces. Thus, substitution in production and consumption are allowed in CGE models. Factor and commodity markets attain their equilibrium through price adjustments. For analyzing the impacts of change in productive capacity of resource-dependent industries, Seung, et al. show that CGE models are more appropriate than other regional economic impact model. For this paper, CGE models are more appropriate than a fixed-price input-output or Social Accounting Matrix models because productivity capacity of some agricultural sectors are curtailed and the impacts of rangeland fire effect economic sectors differently. These differential impacts lead to changes in relative prices, which further leads to reallocation of resource across sectors. Previous studies by Boisvert and Brookshire and McKee suggest that CGE models are advantageous for natural disaster impact analysis. Rose and Guha estimated direct and indirect economic impacts of electric lifeline disruptions cause by earthquakes using a CGE model. However, for this analysis, a dynamic CGE model will be used because rebuilding of ranches and reclamation of rangelands will be a multi-year process.

Model Specification

CGE models explicitly incorporate supply constraints, identify prices and quantities separately and have smooth, twice differential production and preference surfaces. Thus, substitution effects in production and in consumption are allowed in CGE models. Factor and commodity markets attain their equilibrium through adjustment of prices.

Most of the regional CGE models mentioned above are static. However, policy evaluations based on a single period, static equilibria can be misleading (Ballard et al.) since in the real world dynamic elements abound. For a regional economy where many dynamic elements, such as interregional population movements and capital accumulation are observed, it is more appropriate to employ a dynamic specification of a CGE model. This study explicitly incorporates such dynamics into the CGE model. The structure of the dynamic model used in this analysis is based on Adelman et al., Robinson, Ballard et al, Seung and Kraybill, and Seung, et al.

Dynamics

The structure of the dynamic model in this paper is similar to that of Adelman et al., a description of which is found in Robinson. In this paper, there are two kinds of adjustment behavior to be considered (Robinson). First, in the goods market, the adjustments of prices and quantities occur in a short period, say in a year, reducing excess demand to zero (Walrasian equilibria). Second, in factor markets, adjustment takes multiple periods because of lagged responses of factor supplies, represented, for example, by the labor migration elasticity in equation (1) below and the adjustment coefficient in the investment function (equation 2 below) in the present model. The labor migration function is given by:

(1) $$LMIG_t = LSTK\left[\left(\frac{W_t}{WROW}\right)^{LME} - 1\right]$$

where:

$LMIG_t$ denotes the net in-migration of labor in period t;
$LSTK_t$ is the aggregate stock of labor given at the beginning of period t;
W_t is the average wage rate in the study region in period t;
WROW is the average wage rate in the rest of the world (ROW) in period t; and
LME is the labor migration elasticity.
The net investment function in each sector is given by:

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

where:

$NI_{i,t}$ is net investment in sector i in period t;
l_i is adjustment coefficient;
$KD_{i,t}$ is desired capital stock in sector i in period t; and
$K_{i,t-1}$ is capital stock at the beginning of period t.

The investment determined via equation (2) is independent of domestic 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, surplus savings flow out of the region, and vice versa.

Static equilibria are sequenced through time to reflect a change in capital stock, which is due to investment, and a change in labor stock, which is due to labor migration and population growth. The 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. In this study, the sequence of equilibria generated without any policy implementation is called "continuous benchmark" while that generated with a policy shock is called "continuous counterfactual." The policy impacts are calculated by comparing the continuous counterfactual with the continuous benchmark.

Labor income is provided by the IMPLAN data set as employee compensation and proprietor income. All other income is aggregated into an "other property income" category. For the agricultural sectors, it was necessary to allocate other property income into income due to land and capital. Land endowments were estimated using information on land use and valuation from Nevada county governments in the study area. Land acreage and the assessed valuation of that land are available for each county. Income from land or rental value of the annual use of land was inputted from the value of land based on assessed values. Income from land was subtracted from "other property income" category with the remainder assigned to capital. The result allowed sector factors to be assigned to land, labor, and capital for the analysis.

The labor force is assumed to grow at the same rate as the population, and net investment is assumed to be sufficient to make the capital stock grow at the same rate as the population, and net investment is assumed to be sufficient to make the capital stock grow at the same rate. The State of Nevada Demographer's Office (Hardcastle) forecasts population growth rate for the five-county, northeast Nevada study area (Elko, Eureka, Lander, Humboldt, and Pershing Counties) area to be 1.4 percent. Labor is assumed to be mobile between sectors, while capital is sector-specific. Land is assumed fixed in supply so this factor becomes scarce over time, especially during the fire season and rangeland rehabilitation period.

Empirical Implementation

IMPLAN is used to develop ten-sector social accounting matrix (SAM) for the five-county, Northeast Nevada Study Area (Minnesota IMPLAN Group, Inc.). Calculating the effects of policy changes in a CGE model requires specific parameter values for the model equations. Some parameters such as elasticities of substitution and elasticities of transformation are specified on the basis of econometric research. The remaining parameters such as share parameters are then determined by solving the model equations with the base-year observations for model variables and the exogenous parameters substituted in the model. In this study, the adjustment coefficient in the net investment function is set at 0.08 (Treyz). Annual population growth rate for Northern Nevada is set at 1.4 percent.

Data Description

Table 1 summarizes the economic data for the five-county Northern Nevada Study Area. This data was derived from a county-level IMPLAN data set (Minnesota IMPLAN Group, Inc.). Total Agricultural Sector output was $185.292 million, which was 3.90 percent of total study area value of output. Within the agricultural sectors, the Range and Ranch Livestock Sector had the largest value of output of $79.717 million. Total Non-Agricultural Sector output was estimated to be $4,562.770 million, which was 96.10 percent of total study are output. Within the non-agricultural sectors, the Mining Sector had the largest output value of $1,959.402 million.

As for employment, Total Agricultural Sector employment was 2,325 employees or 5.17 percent of total study area employment. Within the agricultural sectors, the Hay and Pasture Sector had the highest employment of 1,077. Total Non-Agricultural Sector employment was 42,612, which was 94.83 percent of total study area employment. Within the non-agricultural sectors, the Service Sector had the highest employment with 13,811 employees.

From Table 1, total value added for the Total Agricultural Sector was $48.929 million, which was 1.91 percent of total study area value added. Within the agricultural sectors, the Hay and Pasture Sector had the highest value added with $18.070 million. Total Non-Agricultural Sector value added was $2,510.610 million, which was 98.09 percent of total study area value added. With the non-agricultural sectors, the Mining Sector had the highest value added of $857.550 million.

Burned Area Emergency Recovery (BAER) teams were established by Congress as a means of providing support to communities within urban and suburban wildland and wildfire interface areas. The BAER teams are comprised of specialists that create sub-teams that are charged with analyzing natural disasters and then developing a comprehensive plan to address the losses associated with the disaster. These are basically first response teams that develop plans that are then fast tracked to Congress for funding.

Table 1. Summary of Economic Data for the Five-County Study Area: Value of Output, Employment, and Value Added, 1999.

Sector	Value of Production (in million dollars)	Percent of Total (%)	Employment (numbers)	Percent of Total (%)	Total Value Added (in million dollars)	Percent of Total (%)
Range and Ranch Livestock	79.717	1.68	578	1.29	16.868	0.66
Sheep, Lamb, and Goats	2.114	0.04	66	0.15	0.425	0.02
Other Livestock	25.113	0.53	97	0.22	6.019	0.24
Hay and Pasture	61.358	1.29	1,077	240	18.070	071
Other Crops	16.990	0.36	507	1.13	7.547	0.29
Total Agriculture	185.292	3.90	2,325	5.17	48.929	1.91
Mining	1,959.402	41.27	7,897	17.57	857.550	33.50
CMTCPU[1]	749.415	15.78	5,041	11.22	314.482	12.29
Trade	356.980	7.52	7,494	16.68	266.850	10.43
F.I.R.E.[2]	396.486	8.35	1,809	4.03	277.409	10384
Services	781.716	16.46	13,811	30.73	502.943	19.65
Government	318.770	6.71	6,560	14.60	291.376	11.38
Total Non-Agriculture	4,562.770	96.10	42,612	94.83	2,510.610	98.09
TOTAL	4,748.082	100.00	44,937	100.00	2,559.539	100.00

[1]CMTCPU stands for the Construction, Manufacturing, Transportation, Communication, and Public Utilities Sector.
[2]F.I.R.E. stands for the Finance, Insurance, and Real Estate Sector.

In response to the large Nevada fire disaster, various teams of professional were organized to address numerous impacts relating to fire. In order to predict economic losses, as requested by federal agencies, state and local elected officials and private landowners, a survey team with expertise in ranch and community economics was formed. The economic survey team-included representatives from the University of Nevada Cooperative Extension, USDA's Natural Resource Conservation Service (NRCS) and Eureka County Public Lands Department. Additional information was provided to the team by Nevada Farm Bureau, Nevada Cattlemen's Association, USDI Bureau of Land Management, Nevada Division of Wildlife, BAER reports and local county officials. This local team was formed at the onset of the fires and was charged with gathering needed information and generating economic impacts.

The economic team utilized a survey instrument to solicit information from private and public landowners and/or managers concerning losses and damages resulting from the fires. The instrument was designed to gather information concerning major losses yet still allow for a quick response time. Survey categories and their corresponding questions were designed in cooperation with those persons impacted, to determine what economic losses would be measured, what amount was lost and for how long would that loss be continued. For example, the instrument included questions on animal unit months (AUM) of forage impacts, miles of fence lost or damaged, type of structures damaged, livestock killed or injured, and ranch inputs devoted to fighting the fires (i.e. labor, supplies, equipment, etc.) Once the instrument was designed, personnel at the county level were assigned to gather the information. Given emergency constraints, all methods of data collection, telephone surveys, mail in surveys, producer meetings, etc. were incorporated to gather the needed information. The methods used depended on resources available in each county. Current data from University enterprise budgets, commodity market reports and input prices were used to assign monetary value.

County data were sent to University of Nevada Cooperative Extension offices in Pershing, Humboldt and Eureka Counties where it was compiled into spreadsheets. Cooperative Extension then generated and distributed economic impact reports to other agencies and public officials.

At the ranch level, data derived from surveys found that total AUM's lost due to the rangeland fires in the study area were approximately 133,180. It is assumed that rangeland used for public grazing of range cattle will not be used for the first two years of rehabilitation. After these two years, range cattle will be gradually introduced back on to the public lands. For this first year (2002), only 25 percent of the AUM's will be allowed, followed in 2003 with 50 percent, following in 2004 by 75 percent and, finally by 2005 the rangeland is assumed to be rehabilitated to support AUM's similar to before the rangeland fires. Also, none of the ranchers in Northern Nevada qualified for federal emergency funding, so there were no expenditures to rehabilitate private lands.

Bureau of Land Management furnished information as to public land expenditures for fire suppression and rangeland rehabilitation. It is assumed that fire suppression and rangeland rehabilitation expenditures occurred during the first year of the rangeland fire (1999). Table 2 shows the federal expenditures on rangeland fire suppression and rehabilitation activities within the five-county study area. The expenditures in the Service Sector are from lodging and firefighters and rehabilitation personnel in local motels and hotels, hiring of contract personnel, and leasing and renting of vans, trucks, helicopters, and airplanes. Since these are expenditures on public lands, there is no private sector insurance coverage.

Table 2. Federal expenditures for rehabilitation and fire suppression by sector

Sector	Rehabilitation Expenditures	Fire Suppression Expenditure	Total Expenditure by Sector
CMTCPU[1]	$19,686	$223,520	$243,206
Trade	$118,297	$887,896	$1,006,193
FIRE[2]	$117,637	0.0	$117,637
Services	$3,383,657	$5,092,208	$8,475,865
Total	$3,639,277	$6,203,624	$9,842,901

[1] CMTCPU stands for the Construction, Manufacturing, Transportation, Communication and Public Utilities Sector.
[2] FIRE stands for Finance, Insurance and Real Estate Sector

RESULTS

Tables 3 and 4 show the cumulative ten-year impacts on sectoral and regional value of output and employment from the rangeland fire in the five county Northern Nevada study area. Table 3 shows that the total regional value of output differences between rangeland fire (counterfactual) scenario and the no rangeland fire (benchmark) scenario was approximately $22.0 million or 0.04 percent less than the continuous benchmark. As for the agricultural sectors, total value of production decreased by $19.8 million or was 1.36 percent less than the continuous benchmark. Given that cattle were not allowed back on the range in numbers prior to the rangeland fire for six years, the Range and Ranch Livestock Sector realized the greatest impacts with a decrease in value of production of $14.84 million or 3.14 percent less than the continuous benchmark.

As for the nonagricultural sector, total value of output decreased only $1.52 million or approximately 0.003 percent less than the continuous benchmark. Given federal fire suppression and rehabilitation expenditures, the Service Sector realized a $3.871 million or 0.04 percent increase in value of production when compared to continuous benchmark values. This increase in the Service Sector is due to the fire suppression and rehabilitation expenditures and the inflow of labor released from the agricultural sectors. Given total study area value of production decreased of $19.8 million when compared to the continuous benchmark, this implies that increased activity by the Service Sector was not enough to offset decreases in the other regional economic sectors from the rangeland fire.

Table 3. Cumulative Impacts of 1999 Rangeland Fire on Sectoral Output Over a Ten-Year Period.

Sector	Benchmark (in million dollars)	Counterfactual (in million dollars)	% Change
Range and Ranch Livestock	472.356	457.516	-3.14
Sheep, Lambs and Goats	25.125	24.998	-0.51
Other Livestock	98.384	97.894	-0.50
Hay and Pasture	377.403	375.518	-0.50
Other Crops	487.242	484.784	-0.50
Total Agricultural Output	1460.51	1,440.71	-1.36
Mining	23,695.296	23,695.449	0.00
CMTCPU[1]	8,115.208	8,111.390	-0.05
Trade	3,723.337	3,722.014	-0.04
FIRE[2]	2,795.338	2,794.935	-0.01
Services	10,968.525	10,972.396	0.04
Total Nonagricultural Output	49,297.704	49,296.184	-0.00
Total Output	50,758.214	50,736.255	-0.04

[1] CMTCPU stands for the Construction, Manufacturing, Transportation, Communication and Public Utilities Sector.
[2] FIRE stands for Finance, Insurance and Real Estate Sector

Table 4. Cumulative Impacts of 1999 Rangeland Fire on Sectoral Employment Over a Ten-Year Period

Sector	Benchmark (numbers)	Counterfactual (numbers)	% Change
Range and Ranch Livestock	3,232	3,097	-4.18
Sheep, Lambs and Goats	570	561	-1.58
Other Livestock	471	463	-1.70
Hay and Pasture	8,247	8,113	-1.62
Other Crops	8,453	8,316	-1.62
Total Agricultural Output	20,973	20,550	-2.02
Mining	101,582	101,583	0.00
CMTCPU[1]	64,936	64,896	-0.06
Trade	83,883	83,840	-0.05
FIRE[2]	11,855	11,848	-0.06
Services	221,350	221,429	0.04
Total Nonagricultural Output	483,605	483,596	-0.00
Total Output	504,579	504,146	-0.09

[1] CMTCPU stands for the Construction, Manufacturing, Transportation, Communication and Public Utilities Sector.
[2] FIRE stands for Finance, Insurance and Real Estate Sector

Table 4 shows that when output is reduced in the agricultural sectors, labor is released from these sectors. The released labor will either be employed by some other nonagricultural sector or out-migrates to the rest of the world. Employment in the agricultural sectors declined by 423 jobs or was approximately 2.02 percent less than the continuous benchmark. Of the agricultural sectors, the Range and Ranch Livestock sector realized the largest job decrease of 135 jobs or approximately 4.18 percent less employment when compared to the continuous benchmark results. As for the nonagricultural sectors, employment decreased by 12 jobs or was 0.002 percent less than the continuous benchmark. The service sector because of federal fire suppression and rehabilitation expenditures and employment of released agricultural sector employment realized an increase of 79 jobs or was 0.04 percent greater than estimates from the continuous benchmark. Overall, employment in the study area decreased by 433 jobs or was 0.09 percent less than the continuous benchmark. However if rehabilitation of the burned rangeland is protracted which means range cattle release upon the rangeland is delayed, difference between the continuous benchmark and counterfactual results will be greater.

CONCLUSIONS

This paper presents a dynamic CGE model of business losses and recovery efforts associated with 1.6 million acres rangeland fire covering a five-county northern Nevada study area. For perspective, the 1.6 million acres is approximately six percent (6%) of the total study area acreage. Dynamic CGE models are especially adept at analyzing the role of markets and prices in the extent of mitigation of economic losses due to the 1.6 million acre rangeland fire.

This paper is only a preliminary application of CGE analysis for potential estimation of rangeland fire impacts. Other applications for future analysis would be to complete a similar analysis but use fixed-price input-output procedures. This could potentially show the advantages of CGE analysis for rangeland fires impact estimation. The results might also support findings by Rose and Guha who found that typical CGE model, even based on short-run versus long-run substitution elasticities, was far too flexible and is likely to understate impacts of a natural disaster. Therefore, Rose and Guha suggest that deliberate efforts should be taken to incorporate real world rigidities as well as resiliency in the typical CGE model for natural disaster impact estimation.

Also additional analysis could investigate the impacts and welfare impacts of added federal fire fighting expenditures. Following procedures by Seung et al. and Schreiner et al., the costs-benefits of the added federal fire fighting expenditures could be estimated. For this example, there was little if any recreation on the public lands of this 1.6 million acre fire. However, if outdoor recreation existed, the impacts of reduced outdoor recreation would have to be included in the analysis. Also, labor was assumed mobile between all sectors. Another analysis could separate labor between agricultural and non-agricultural labor and allow alternative factor mobility outside the study area. Lastly, improved rangeland production data would greatly enhance the production responses to rangeland fires that are primary input to the CGE analysis.

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